Towards Energy Recovery from Waste in Developing Countries: An Analysis of the Challenges, Barriers and Prospects of Waste Management in Abuja, Nigeria

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Dedication

I wish to dedicate this piece of research to the most important women in my life, to my lovely wife, **Glory Ojiji** and our two beautiful daughters, **Zara Ojiji** and **Talia Ojiji**, and finally to a daughter of Zion, my late mother, **Rose Ojiji.**

Declaration

This thesis is presented in accordance with the regulations of The University of Salford for the conferral of a PhD through original research. The researcher affirms that no part of the research discussed in this thesis has been previously submitted to support an application for any other degree or qualification, whether from this university or any other academic institution. The researcher has conducted the entirety of this research, and due attribution has been given to all sources of information referenced within.

List of Abbreviations

AEPB	Abuja Environmental Protection Board
CBA	Cost-Benefit Analysis
CE	Circular Economy
CEA	Cost-Effectiveness Analysis
DEFRA	Department for Environment Food and Rural Affairs
EPA	Environmental Protection Agency
EU	European Union
FCT	Federal Capital Territory
GHG	Greenhouse Gases
GWG	Global Warming Potentials
IEA	International Energy Agency
ISWM	Integrated Solid Waste Management
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
MCDA	Multicriteria Decision Analysis
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
NES	The Nigerian Environmental Society
NGOs	Non-Government Organisations
OECD	Organisation for Economic Cooperation and Development
SWM	Sustainable Waste Management
UK	United Kingdom
UN	United Nations
WFD	Waste Framework Directive
WtE	Waste to Energy

COVID-19 Impact Statement

The emergence of the COVID-19 pandemic in the United Kingdom in January 2020 profoundly impacted the trajectory of this research project. The rapid government response, including school closures and the implementation of lockdowns and travel restrictions, significantly affected the planned data collection phase, originally scheduled to begin in April 2020. This section provides an overview of how the pandemic disrupted the research journey.

The research journey commenced in January 2019. By the end of that year, an interim assessment was conducted to evaluate the research framework and preparedness for the primary data collection phases following pilot studies. The research involved two distinct data collection stages: a quantitative phase comprising a questionnaire survey and waste composition analysis and a qualitative phase involving focus group meetings and interviews. The study area is Nigeria, so travel was essential for data collection. However, due to the pandemic, travel became unfeasible, temporarily suspending data collection while closely monitoring the situation. The closure of schools further complicated matters as it meant the loss of access to personal office space and the school library. Balancing research responsibilities with caring for a young family, including a toddler, in a makeshift home office space presented significant mental and logistical challenges.

Despite these formidable obstacles, efforts to advance the research continued through online training, participation in conferences, and supportive interactions with the University office. These interactions facilitated the establishment of a network of experts in the field, including members of the Chartered Institution of Waste Management (CIWM), research colleagues, and various stakeholders in the Nigerian waste management sector.

In response to the evolving circumstances, a pivotal decision was made in January 2021 to adapt the research methodology. This adaptation involved transitioning from traditional door-to-door questionnaire surveys to online surveys. This change was necessitated by the ongoing lockdown measures, travel restrictions, concerns regarding the health risks associated with paper surveys, and the temporary suspension of research fieldwork in Nigeria. Subsequently, an online survey was conducted, and the data were analysed in preparation for the next data collection phase.

By the last quarter of 2021, restrictions had begun to ease, allowing for the commencement of the waste composition study in Nigeria. However, the enduring effects of the pandemic were still apparent, with individuals remaining cautious about engaging in traditional face-to-face interactions due to COVID-19 concerns; this posed data-gathering challenges, exacerbated by the fact that many government agencies, including the Abuja Environment Protection Board (AEPB), were not operating at total capacity. Despite these hurdles, the waste audit was successfully conducted, but the sample size was limited due to time constraints. Furthermore, following consultations with intended participants and research supervisors, it was determined that the focus group discussions (FGDs) would be conducted online.

The adaptations to accommodate the challenges posed by the pandemic were not unique to this study; colleagues in the research community also faced similar adjustments, particularly in their research methods. The limitations section of this report discusses some of the implications of these adaptations.

Abstract

Waste management is a pressing global concern with far-reaching environmental, social, and economic implications. Proper waste management is crucial for sustainable development and achieving a cleaner environment. Studies have projected that the amount of waste generated, especially in most developing countries, is expected to increase by more than three times by 2050. While developing countries still struggle with open dumping and other poor waste practices, developed countries driven by strict policy frameworks use advanced technology waste treatment options and achieve high landfill diversion rates.

Despite its commitment to achieving the UN Sustainable Development Goals (SDGs), Nigeria, like many countries in Sub-Saharan Africa, is faced with the problem of effective management of municipal solid waste (MSW). Growing concerns about dwindling natural resources and the need for energy security have triggered the interest of governments in waste-to-energy technologies. However, in more advanced economies, these technologies are supported by efficient waste management systems, knowledge of waste characteristics and comprehensive legal frameworks, which are deficient in the country.

Using Abuja, the nation‘s capital, as a case study, this research synthesises evidence by exploring current trends in waste management to determine the prospects of implementing WtE technologies in Nigeria. Guided by a pragmatic approach, an explanatory sequential mixed methods design was employed using surveys and focus group discussions to gain various stakeholder perspectives.

The findings show that due to social, regulatory, financial, and natural barriers like inadequate environmental budgets, a lack of environmental education programmes, and an unregulated informal sector, Abuja’s waste management system struggles with inefficient waste collection, a lack of recycling and segregation practices, and open dumping.

Using an Ordinal Logistic Regression (OLR) model, this study found that employment status and income significantly influence participation levels, with low overall participation. After adjusting for all variables, the analysis showed that unemployed individuals and civil servants were less likely to participate, and participation declined significantly as income levels increased. Furthermore, the waste composition study revealed a current per capita generation rate of 0.66kg/capita/day, amounting to about 1,568 tonnes of MSW generated daily in the metropolis.

A synthesis of the findings showed that while the waste composition and quantities point to the potential for energy recovery from MSW using conversion methods like anaerobic digestion and incineration, adequate steps must be taken by the government by implementing Integrated Solid Waste Management strategies, strengthening policies and making financial commitments aimed at creating the enabling environment for the implementation of these technologies. Additionally, adequate assessments are recommended for technology selection using a comprehensive decision-making analysis tool like MCDA.

Chapter 1: Introduction to Study

1.1. Introduction

Waste generation is a natural product of urbanisation, economic development, and population growth (Wilson & Velice, 2015). According to a report by Kaza and Bhada-Tata (2018), the world generates 2.01 billion tonnes of MSW annually and is expected to increase to 3.40 billion tonnes by 2050. Moreover, the report predicts that most developing countries' waste is expected to increase by more than three times by 2050. This tremendous rise in the fast-growing cities of developing and emerging countries has led to increasing public concerns with regard to the resultant health and environmental consequences of this trend. As citizens and decision-makers become more sensitive to environmental pollution and its impact on their quality of life, municipal solid waste management (MSWM) is gaining importance on the local political agenda, and various waste management approaches are being considered.

In their quest for sustainable solutions aimed at achieving the Sustainable Development Goals (SDGs), many developing countries, including Nigeria, are considering WtE as a solution to the problems associated with rising waste quantities in expanding cities as well as rapidly growing energy demands (Mutz *et al.*, 2017). According to Vukovic and Makogon (2022), WtE initiatives have the potential to contribute significantly to SDG 7 and SDG 11 achievement. The focus of these goals is ensuring access to affordable and clean energy and making cities and human settlements inclusive, safe, resilient, and sustainable. The authors explain that by harnessing the energy potential of waste materials, WtE technologies promote sustainable development, renewable energy generation, and efficient waste management practices. These processes produce electricity and heat directly through combustion. Alternatively, they might produce a combustible fuel such as methane or methanol from the treatment of waste materials. These requisites have made WtE technologies attractive to most developing countries.

For example, in Ethiopia, the government has embarked on a significant WtE plan by initiating the Reppie WtE Project in Addis Ababa (Le Picard, 2019). This innovative project addresses the dual challenges of burgeoning waste accumulation and the need for sustainable energy sources. According to Le Picard (2019), the Reppie project plans to convert MSW into electricity through advanced incineration technology, alleviating the strain on landfills and contributing to the local energy grid.

Similarly, India has witnessed noteworthy strides in WtE initiatives. The Okhla WtE Plant in Delhi is a prime example. This facility utilises combustion processes to convert MSW into electricity, producing a valuable energy resource while reducing the volume of waste destined for landfills (Angmo & Shah, 2020). The WtE Research and Technology Council has undertaken research and development efforts to explore effective WtE solutions in Thailand. Their work encompasses diverse technologies such as anaerobic digestion, pyrolysis, and incineration, aiming to convert waste into useful energy forms (Tozlu *et al*., 2016).

When shifting to developed countries, the adoption of these alternative treatment methods has become evident. In 2012, the United States produced substantial electricity, totalling 14.5 million MWh, through 84 WtE facilities (Michaels, 2014; Kumar & Samadder, 2017). According to a report by CEWEP (2020), more than 504 WtE plants are operational in Western Europe. The report also notes that the United Kingdom has about 54 operational WtE plants and additional projects in progress. Similarly, Bajic *et al*. (2015) reported 102 operational WtE plants generating electricity in Japan. China has equally made heavy investments in WtE, with incineration being the most widely used option in the country. Cui *et al*. (2020) report that as of 2018, China had about 331 incinerators with an aggregate designed annual capacity of approximately 133.08 million metric tons, and these incinerators collectively processed around 44.67% of the total collected municipal solid waste (MSW), amounting to approximately 101.84 million metric tons.

In the broader context, countries have also recognised the role of waste management in achieving the SDG framework's goals and are making efforts toward developing sustainable waste management systems (Kaza & Bhada-Tata, 2018). Despite these strides, the rapid urban growth in developing countries has led to poor waste management practices and various challenges (Boateng *et al*., 2019; Ferronato & Toretta, 2019; Khatib, 2012; Hettiarachchi *et al*., 2018), which can hinder the development of WtE projects. According to these researchers, the entire waste management process, encompassing waste generation through its final treatment or disposal, is plagued by numerous factors that undermine efficiency and sustainability in these nations. These contributing factors are insufficient waste collection systems, subpar recycling behaviours, a lack of public awareness and involvement, and inadequate waste segregation practices.

On the other hand, in developed countries, waste recycling and recovery have become the focus of integrated waste management. A report by Defra (2013) indicated a trend of movement up the waste hierarchy by focusing on increasing recycling rates, emphasising waste prevention and reuse, setting zero waste to landfill targets, and energy recovery. The report notes that several European countries, including the Netherlands, Belgium, Denmark, Germany, Austria, Sweden, and Switzerland, have significantly tried diverting a substantial portion of their waste from landfills by implementing effective recycling and composting facilities.

More recently, circular economy (CE) and sustainability have gained increasing traction within academic and practitioner circles (Homrich *et al.,* 2018; Sehnem *et al.,* 2019). The CE strategy encourages the maximum utilisation of scarce natural resources (Sehnem *et al.,* 2019). From the CE perspective, the manufacturing circle can be transformed into a closed loop where waste is reduced or reused as inputs for new products, thereby minimizing the consumption of scarce natural resources (Homrich *et al.,* 2018). The concept emerges as a pivotal pathway toward achieving sustainability, as emphasised by Geissdoerfer *et al*. (2017). In this perspective, solid waste transcends its traditional status as mere rubbish and assumes the role of a valuable resource. The paradigm shift entails the obligation of recovering and reclaiming waste through recycling and reuse, and the conventional notion of waste as a passive by-product of production undergoes a profound re-evaluation. Instead, it emerges as a proactive resource with intrinsic potential for production. This conceptual shift, as suggested by Gregson *et al*. (2015), redirects the focus of MSWM from a linear trajectory of waste generation and disposal to an integrated and circular approach where waste materials become the cornerstone for new production processes.

According to the principle of the CE model, the recovery of energy from waste is an essential aspect of waste management (Ezeudu & Ezeudu, 2019). Using energy from waste helps treat non-reusable and non-recyclable waste and convert valuable energy resources into electricity and heat (Eboh *et al*., 2019; Thomas & Soren, 2020). There are several advantages of recovering energy from MSW, such as providing local sources of renewable energy and decreasing the volume of solid waste dumped in landfills, which in turn may have positive effects on carbon emissions since this process avoids methane emissions from landfills and carbon dioxide from fossil fuels (Scarlat *et al*., 2019).

1.2. Problem Statement

Empirical evidence from studies suggests that over the next few years, Nigeria's role in the global waste management mix will be crucial (Kaza *et al*., 2018). Situated in Sub-Saharan Africa (SSA), Nigeria presently boasts a population of more than 200 million people, projected to surpass 350 million by the year 2050 (UN, 2017). This projection is expected to make Nigeria the third most populous country in the world by 2050. Although ranked among the emerging economies due to its prospects for economic development, Nigeria is still classified as a lower middle-income country in the latest World Bank income classification index. Despite recent advancements in Nigeria‘s socio-economic conditions, the nation‘s human capital development is still a significant concern, as evidenced by its 150 out of 157 countries ranking in the World Bank‘s 2020 Human Capital Index (World Bank, 2021). Nigeria remains confronted with substantial developmental obstacles, such as reducing its heavy reliance on oil exports and revenues, diversifying foreign exchange sources, bridging infrastructure disparities, establishing robust and efficient institutions, addressing governance challenges, and enhancing the effectiveness of public financial management systems (World Bank, 2023).

Likewise, various social and economic factors are challenging Nigeria's current waste management practices' adequacy and sustainability. Despite generating more than 32 million tons of solid waste annually, of which 2.5 million tonnes is plastic waste, it is estimated that only 20-30% is collected in all 36 states of the federation (Ogundele *et al*., 2018). Furthermore, it was estimated that as of 2021, Nigeria contributed approximately 18,640 tonnes of plastic waste dumped in the ocean (WPR, 2023). However, in response to these challenges, Nigeria is taking significant steps to emphasise sustainability as a fundamental aspect of its development agenda. This commitment is reflected in various policy initiatives, international agreements, and domestic strategies to foster a more sustainable and resilient future. The nation‘s participation in global sustainability frameworks, such as the United Nations Sustainable Development Goals (SDGs), further exemplifies its dedication to addressing pressing issues encompassing waste management, renewable energy, climate change, and environmental protection (Oleribe *et al*., 2016). Also, as a signatory to the SDGs, Nigeria’s Renewable Energy Master Plan (REMP) seeks to increase the supply of renewable electricity from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030 (Amulah, 2022).

In Nigerian cities, the responsibility for waste management predominantly rests with state government agencies, often constrained by limited resources and capabilities to effectively address the intricate challenges of solid waste management within their urban areas (Kadafa, 2017). However, like many developing countries, Nigeria is plagued with inefficient waste management systems incapable of handling the current situation (Ezeah & Roberts, 2012; Kadafa, 2017; Nnaji, 2015; Raimi *et al.,* 2019). This situation has created a void that the expanding informal sector has stepped in to fill, playing a significant role in the overall waste management landscape (Ogwueleka & Naveen, 2021).

Within Nigeria, Abuja holds a dual identity as a pivotal entity– functioning as a Federal Capital Territory (FCT) and a city, standing as the nation‘s esteemed capital. This unique status bestows Abuja a multifaceted role encompassing administrative and urban functions. As the FCT, Abuja serves as the epicentre of Nigeria‘s federal government activities, housing crucial governmental institutions, national offices, and diplomatic enclaves. In this capacity, it is responsible for orchestrating the nation‘s administrative and governance affairs (Abubakar, 2014). Concurrently, Abuja is a meticulously pre-planned urban city designed with foresight to alleviate the weight of congestion and inadequate infrastructure that once encumbered Nigeria‘s previous capital, Lagos state (Adama, 2012). According to Abubakar (2014), this deliberate urban planning was conceived to mitigate the challenges posed by overpopulation and deficient infrastructure in the former capital, paving the way for a modern metropolis that could seamlessly accommodate the growing demands of a dynamic nation. Hence, Abuja sets an example of purposeful urban design and governance in Nigeria. While these attributes make it an ideal testing ground for new technologies aimed at fostering better living standards, it has been reported by previous researchers that

Abuja, like other Nigerian cities, is facing various challenges with waste management as a result of rapid urbanisation and population growth (Gajere *et al*., 2019; Kadafa, 2017; Ogwueleka, 2013). Hence, adequate evaluation of its waste management system is necessary to enhance an enabling environment for WtE technologies.

Figure 0.1 *Map of Nigeria highlighting its capital city, Abuja FCT*

Note: From World Atlas Maps

Apart from the existing challenges associated with MSW management, Nigeria faces a significant hurdle in addressing its inadequate electricity generation. The rapid population growth, particularly in urban areas, has exacerbated the already pressing issue of electricity scarcity (Aliyu & Amadu, 2017). According to the International Energy Agency (IEA) report (2017), a substantial portion of Nigeria's population, approximately 40%, still lacks consistent access to electricity. Furthermore, the issue of energy security is of paramount concern. Nigeria's heavy reliance on traditional fossil fuels for energy generation leaves the country vulnerable to supply disruptions and price fluctuations in the global energy market. This dependency hinders the nation's ability to ensure a stable and consistent energy supply for its growing population and industries. This glaring deficiency in the nation's electricity infrastructure underscores the urgency and importance of adopting WtE solutions as a potential means to address the waste management challenges and the energy crisis. However, the success of these WtE facilities in developed countries is attributed to well-structured waste management systems, a deep understanding of waste characteristics, comprehensive legal frameworks, and the effective selection of appropriate technologies (Mutz *et al*., 2017).

1.3. Research Gaps

The UNEP (2018) report on waste management in Africa highlights a significant concern regarding the impact of changing lifestyles and consumption patterns, particularly within the expanding urban middle class in various cities like Abuja. This shift contributes to the growing complexity and varied composition of waste streams across the African continent. However, according to Edjabou *et al*. (2015) and Nnaji (2015), insufficient and dependable data concerning waste generation and composition remains a notable challenge. An example of conflicting waste management data is a recent study conducted in 2018 by the Japan International Corporation Agency (JICA), which reported waste generation in Abuja as 0.50kg/capita/day; this shows a decrease from the 0.634kg/capita/day reported by Ogwueleka in 2013, despite both studies employing similar methods. Considering the rate of development and economic appreciation Abuja has undergone over the years, waste generation per capita is expected to increase rather than decrease, as Hoornweg and Bhada-Tata (2012) posited.

Such inaccurate data hinders the strategic planning and assessment of waste management initiatives and is also pivotal for optimising resource recovery processes. Moreover, other researchers have similarly argued that Nigeria currently does not have an actual estimate of the MSW generation and composition from households, industries as well as other waste sources (Abila, 2014; Ezendu & Ezendu, 2019; Kadafa, 2017; Oteng-Ababio, 2014). Ike *et al*. (2018) came to a similar conclusion. They urged the Nigerian government to overhaul all existing waste management systems to accommodate recent technologies and policies, encourage academic research and training in this field, and prepare to put the recommendations from such studies into practice.

While some of the existing waste management policies in Nigeria have been largely criticised, there is a lack of research investigating the social dimensions of the ineffectiveness of these policies. One such policy criticised by Olowoporopku (2017) and Danbaba et al. (2017) is the National Environmental Sanitation Policy 2005, which sets aside regulations mandating the public to participate in sanitation and waste management exercises on a particular day of the month. Despite the criticism for poor implementation and lack of public participation, no study investigated the influence of socioeconomic and demographic factors on public participation in the exercise.

In the context of energy recovery from waste, various studies have focused in recent years on the community-level assessment of the energy recovery potential that could be derived from MSW in Nigeria (Alao *et al*., 2020; Somorin *et al*., 2017; Ogunjuyibe *et al*., 2017; Olujobi *et al*., 2021). One such study was conducted by Ogunjuyibe *et al*. (2017) on the electricity generation potential of MSW in different Nigerian cities, comparing incineration, LFGR and AD. Based on different parameters, these studies proposed the suitability of these technologies and opted for AD as a more favourable choice. Such scholarly accomplishments testify to the growing emphasis on unravelling the latent energy potential in Nigeria’s MSW landscape.

However, these research papers were more of a techno-economic feasibility study and rarely related to the socioeconomic parameters of waste management, which is necessary to capture the inherent challenges due to the increasing waste quantities. MSW is a product of social and economic interactions within communities, so its management holds significant social implications (Ezeudu & Ezeudu, 2019). Hence, in proffering WtE solutions, it is crucial to evaluate the status of waste management systems to present a broad perspective necessary to create the enabling environment for a sustainable future. Furthermore, accurate waste management data is crucial to initiating and implementing advanced systems, including WtE technology. Therefore, Nigeria's paucity of such data puts decision-makers judgements at risk and can impact investors' forecasting.

With a focus on household MSW, this study attempts to fill these identified gaps. Firstly, the study seeks to update existing knowledge by exploring the current state of waste management in Abuja. The research also intends to establish a baseline for future characterisation and quantification of MSW to help formulate sustainable waste strategies in Abuja. By delving into the social and technical dimensions, this study offers a holistic understanding that can inform policy formulation, drive sustainable practices, and contribute to advancing waste management strategies in developing countries.

1.4. Research Aim and Questions

This research aims to synthesise evidence by examining the current status of waste management in Abuja and identifying the barriers and prospects towards WtE development in Nigeria.

Based on the above premise, the research attempts to address the following key questions:

RQ1: What is the current state of Waste Management in Abuja?

RQ2: What sociodemographic and economic factors influence public participation in environmental sanitation in Abuja?

RQ3: What is the current estimated per capita waste generation and the daily amount of waste generated in Abuja?

RQ4: Does socioeconomic status influence waste generation and composition in Abuja?

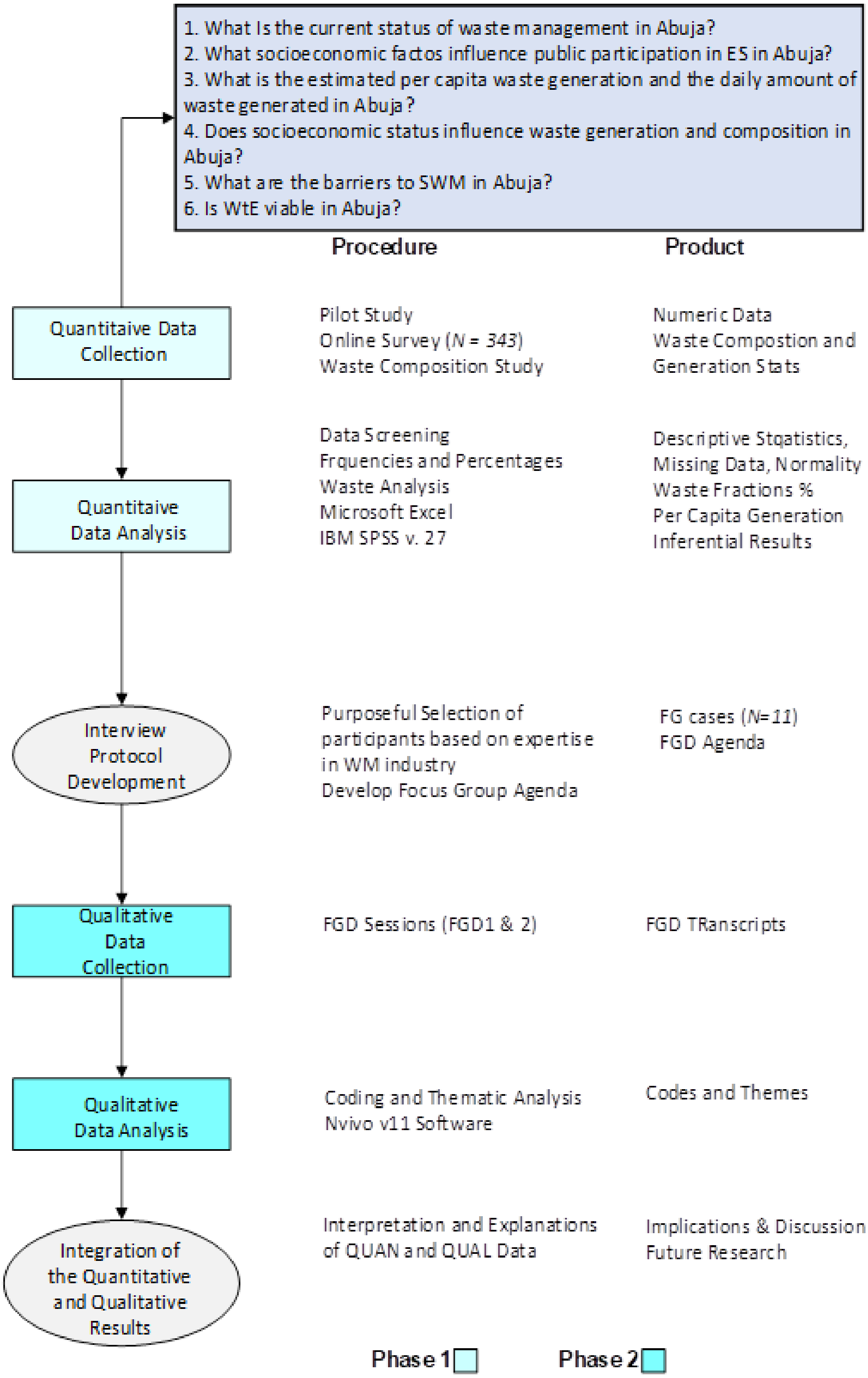
RQ5: What are the barriers to sustainable waste management in Abuja?

RQ6: Is WtE Viable in Abuja and Nigeria?

1.5. Research Methodology

The research methodology employed for this study follows a pragmatist research approach, which combines surveys and semi-structured interviews in two distinct phases (Figure 1.2). This approach aligns with the perspective of Saunders *et al*. (2016), who suggest that using multiple research approaches can help mitigate the limitations of relying solely on one method or counteract potential biases associated with another method. By integrating the data from both phases, this study aims to achieve a more comprehensive and balanced understanding of the research topic.

Figure 0.2 *Research Methodology Process*



1.6. Structure of Thesis

This thesis comprises eight chapters. Each chapter is briefly introduced as follows:

Chapter One: Introduction to Study

This chapter overviews the research‘s foundational aspects, beginning with the research background. The research problems and rationale are followed by the questions driving the study and the overall aim. The concluding part gives a schematic outlook of the methodology before briefly introducing each chapter.

Chapter Two: An Overview of Waste Management Trends

This chapter provides a comprehensive literature review relevant to the study. It encompasses fundamental knowledge, concepts, and definitions of keywords and terms central to the research. The literature review thoroughly examines all the areas specified in the research objectives, comprehensively analysing the current academic discussions.

Chapter Three: Methodology

This chapter outlines the research philosophy, design, methodology selection, data analysis techniques, and procedures and rationalizes the study's approach. Furthermore, it covers the research methodologies, including the study's data collection and analysis methods.

Chapter Four: A Cross-sectional Survey of Waste Management in Abuja

Chapter Four presents the results of the survey questionnaires and discusses the analysis of the 343 valid responses.

Chapter Five: Current Trends in Waste Generation and Composition

This chapter highlights the results of the waste composition study and discusses the key findings that address the underlying research questions.

Chapter Six: A Qualitative Perspective of Waste Management in Abuja

This chapter presents the results from the analysis of the FGD transcripts. It includes a brief discussion, which marks the initial integration of the findings from the previous chapters.

Chapter Seven: Energy Recovery from Waste in Abuja

Chapter Seven serves as a comprehensive discussion chapter that combines the implications of the entire study. It facilitates a cohesive understanding of the broader significance of the study‘s results.

Chapter Eight: Conclusions and Recommendations

This chapter concisely summarises the fundamental research findings and highlights the accomplishment of the research aim and guiding questions. It also outlines the research limitations and provides insightful recommendations for future research avenues.

Chapter 2: An Overview of Waste Management Trends

2.1. Introduction

Waste emerges as an unavoidable consequence of human activities, tracing its origins back to the very beginnings of communal living. In recent times, the surge in population, rapid economic expansion, swift urbanisation, and improved living standards within communities have notably escalated the rate of MSW generation in developing countries (Kadafa, 2017; Kaza *et al*., 2018). The responsibility of establishing an effective and efficient waste management system for urban residents largely falls on municipal authorities. However, these authorities frequently confront challenges that extend beyond their immediate control. These challenges are often rooted in policy deficiencies, financial constraints, the intricate nature of waste management systems, and their multifaceted dimensions (Guerrero *et al*., 2017).

This chapter provides an overview of the relevant literature reviewed so far, supporting and aligning with the research questions formulated in the study. It starts by explaining definitions of waste and giving an overview of its global projections and consequences. As the chapter progresses, the literature narrows into exploring waste management in Nigeria, highlighting the challenges while examining current literature on trends in waste generation and composition, policies and regulations, and stakeholder involvement. Furthermore, the chapter overviews some WtE technologies and highlights essential decision-making tools. The theoretical models guiding the study are introduced within the discourse before summarising the chapter.

2.2 Municipal Solid Waste: Definitions and Consequences

Improving the standard of living, advancement of social economies, and growing global population have resulted in an uncontrolled increase in the volume of MSW, posing a severe environmental threat (Karak *et al.,* 2012; Joshi & Ahmed, 2016). MSW is a collective description of waste generated from domestic activities collected and treated by municipalities (Vergara & Tchobanoglous, 2012). In another definition, MSW is described by Inglezakis *et al.* (2018) as waste streams generated in urban areas collected and treated by or for municipalities or other local authorities. Thomas and Soren (2020), from the Indian scenario, define MSW as waste generated from households and any other waste which has a similar composition and properties as household waste. In essence, MSW may cover household waste, including bulky waste, commerce and trade, office buildings, institutions, small businesses, yard and garden waste, street sweepings, and the contents of litter containers (OECD, 2019).

Given the different definitions, Plaza and Lambertucci (2017) posit that the categorisation of MSW into various classifications is often subject to influence based on the different definitions of practitioners and professionals in the field. However, the European Commission, to harmonise the definition, describes MSW under three categories:

i. *"mixed waste and separately collected waste from households including paper and cardboard, glass, metals, plastics, bio-waste, wood, textiles, waste electrical and electronic equipment, waste batteries and accumulators; bulky waste, including mattresses and furniture; garden waste, including leaves, grass clipping".*

ii. *"mixed waste and separately collected waste from other sources that are comparable to household waste in nature, composition and quantity".*

iii. "*market cleansing waste and waste from street cleaning services, including street sweepings, the content of litter containers, waste from park and garden maintenance".*

Similarly, the United States Environmental Protection Agency (EPA, 2016) define MSW to include waste from homes, institutions, and commercial sources consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. This MSW definition excludes municipal wastewater treatment sludges, industrial process wastes, automobile bodies, combustion ash, and construction and demolition debris.

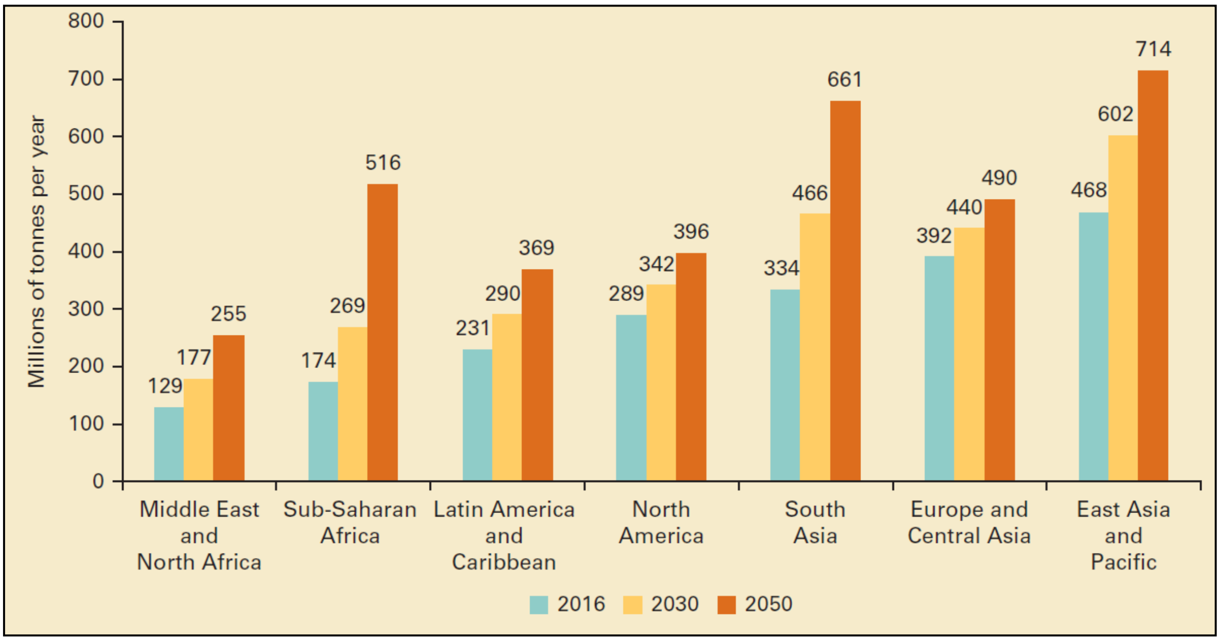
Unifying these definitions, researchers agree that MSW management is complex and requires the harmony of various interrelated aspects with inputs from legal, economic, governmental, political, administrative, and environmental stakeholders (Hoornweg & Bhada-Tata, 2012; Masebinu *et al*., 2017) and that the escalating quantity of MSW worldwide, particularly in developing countries, is a pressing issue. This surge is primarily linked to urbanisation and the consequent rise in human activities, as emphasised by studies such as those conducted by Hoornweg and Bhada-Tata (2012) and Joshi and Ahmed (2016). While these challenges are more commonly observed in developing countries, it is important to note that the issue also impacts developed countries (Yusuff & Zakaria, 2012). In 2016, it was recorded that 17 billion tonnes of MSW were generated globally, of which 1.3 billion tonnes were generated from cities (Chattopadhyay *et al.*, 2009). This figure was estimated to rise to 2.2 billion tonnes by 2025 due to the high rate of urbanisation in low- and medium-income countries (Hoornweg & Bhada-Tata, 2012) and the overall generation of MSW estimated to increase to 27 billion tonnes in 2050 (Albores *et al*., 2016).

In the US, the total volume of MSW generated in 2017 was 267.8 million tonnes, approximately 5.7 million tonnes more than the amount generated in 2015; approximately 2.046kg of MSW generated per person per day (Alamu *et al*., 2021). In the EU, 220 million tonnes of MSW was generated in 2018 (Eurostat, 2020); this was higher than the volume of MSW generated in 2017 (218 million tonnes). In terms of the volume of MSW generated yearly per person among the EU member states, Denmark led the way with 766kg per person, with Malta (640kg), Germany (615kg) and Luxembourg (610kg) being the other countries generating more 600kg per person.

According to a World Bank (2018) report, 174 million tonnes of MSW were generated in 2016 in Sub-Saharan Africa at a rate of 0.46 kilograms per capita per day; this amounts to approximately 180 kg per person per year, far less than that of the EU countries. As illustrated in Figure 2.1, the projections provided by the World Bank depict the anticipated trends in waste generation across different regions. Notably, Sub-Saharan Africa emerges as the fastest-growing region regarding waste generation. The projections suggest that the volume of MSW generated in this region is poised to nearly triple by the year 2050.

Moreover, the report's findings highlight a distinct pattern in waste generation per capita between developed and developing countries. Specifically, the data indicates that the amount of waste generated per person per day tends to be higher in developed countries. This observation has suggested a positive correlation between income levels and waste generation (Vieira & Matheus, 2017; Noufal et al., 2020).

Figure 0.3 *Waste Generation Quantity Projections by Region*



*Note. F*rom Kaza *et al*., 2018

The accumulation of MSW negatively impacts public health, natural resources, socio-economic development, and the environment (Jagun *et al*., 2022). As regards the environment, the resultant effect of poor MSW disposal is the emission of greenhouse gases (GHGs), which results in global warming (Johari *et al.,* 2012; Nema *et al.,* 2012). Methane (CH_4) and carbon dioxide (CO_2) are the two critical by-product gases of MSW that cause significant environmental degradation (Xiaoli et al. *et al.,* 2010; Johari *et al.,* 2012). Though carbon dioxide tends to be more concentrated in the atmosphere, methane has a more negative impact. Research has shown that methane has more than twenty-five times more effect than carbon dioxide, accounting for 20% of the global greenhouse gas effect (Yusuf *et al.,* 2012; Aleluja & Ferrao, 2016).

Human-induced sources of methane (CH4) emissions include landfills, crude oil exploration, mining activities, agricultural activities, and other industrial activities (Yusuf *et al.,* 2012; Aleluja & Ferrao, 2016). Despite its negative effect on the environment, methane has a distinct advantage as a source of green fuel that can be used to generate electricity and heat (Johari *et al.,* 2012). Energy is essential to economic and social development and leads to improved quality of life. With the growing global population and resultant waste quantities, such alternative energy is essential to sustaining human existence (Noor *et al.,* 2013). Regrettably, the full potential of energy recovery from MSW has yet to be realised, particularly in developing countries (Khan *et al*., 2022). Additionally, with the ongoing depletion of natural resources, this issue remains a pressing concern.

The discussion so far has highlighted projections that could result in a severe waste management crisis and environmental consequences, particularly in SSA and Asia. Although many countries in these regions struggle with waste management in similar capacities, the statistics show that these would continue to increase, emphasising an urgent need for SWM solutions. In this context, various researchers have focused on the challenges and barriers to SWM in developing countries (Aderoju, 2020; Duru *et al*., 2019; Ezeah & Roberts, 2012; Faniran *et al*., 2017; Joseph *et al*., 2020; Kadafa, 2017; Ike *et al*., 2018; Marafa & Magami, 2019; Nnaji, 2015; Ola & Suleiman, 2022; Umar *et al*., 2022). However, due to the detrimental cycle of issues regarding waste management, researchers often use the words “challenges” and “barriers” in the same context. In this study, “challenges” describe problematic issues of the waste management cycle, mainly integrated into the public domain between waste generation and disposal. At the same time, “barriers” refer to overarching issues that emerge mainly from an administrative perspective.

2.3. Municipal Solid Waste Management in Developing Countries

The last two decades have seen growth in the volume of generated waste in developing economies; the sub-Sahara Africa continent is the fastest-growing region in waste generation (Figure 2.2). Existing literature indicates that in developing countries, household waste represents the highest percentage, followed by commercial or market wastes and then varying quantities from street, industrial and institutional wastes (Abdel-Shafy & Mansour, 2018; Noufal *et al*., 2020). MSW in these areas is mainly generated from various sources influenced by human activities; this implies that the generated waste is usually heterogeneous with different physical characteristics composed of food waste, rubbers, wood, plastics, papers, metals, agricultural wastes, and e-waste such as refrigerators, food processors and other electrical appliances (Abdel-shafy & Mansour, 2018).

According to Kadafa (2017), this heterogeneity makes it more challenging to implement efficient recycling processes and convert waste into valuable raw materials. The challenges posed by heterogeneous waste composition are only one aspect of the more significant issue. Throughout the waste management process, from its generation to its eventual treatment or disposal, multiple factors contribute to the inefficiency and unsustainability of waste management systems in these countries (Jagun *et al*., 2022). These factors include inadequate waste collection mechanisms, poor recycling habits, limited public awareness and participation, and poor waste segregation practices (Ezeah & Roberts, 2012; Ferronato & Toretta, 2019). Inefficient waste collection practices can result in inadequate waste sorting and mixing of different waste types, exacerbating the challenges of dealing with heterogeneous waste composition (Ogwueleka, 2013). Furthermore, Aderoju *et al*. (219), Abdel-shafy and Mansour (2018), and Ferronato and Toretta (2019) have noted that the lack of well-structured waste collection systems often leads to open dumping, a practice where waste is disposed of without proper containment or treatment; this contributes to environmental pollution and health hazards and exacerbates the difficulties of managing diverse waste streams effectively (Ferronato & Toretta, 2019).

Public awareness and participation are crucial elements in sustainable waste management. Lack of awareness of proper waste disposal practices and inadequate participation in recycling or waste management initiatives exacerbates the problems associated with waste accumulation, environmental contamination, and the strain on existing waste management infrastructure (Olukanni *et al*., 2016); this is also blamed on the fact that people are unaware of the potential value of waste as a resource, which leads to inefficient waste disposal practices (Ogwueleka, 2013). The challenge of open dumping also extends to different parts of Asia. For example, it has been reported that open dumping accounts for 60% of final waste disposal in Thailand (Ferronato & Toretta, 2019). Such a high percentage of open dumping practices has also been reported in India. Recent studies provide evidence of a deteriorating situation in India, where more than 90% of MSW is reportedly disposed of in open landfills (Kumar & Agrawal, 2020).

Additionally, the collection coverage in urban areas often falls below 60%. Joshi and Ahmed (2016) attributed the poor MSW disposal practices in India to inefficiency in waste collection and the inadequacy of sanitary landfilling facilities, prompting the citizens to dispose of MSW in open lands. In a recent study by Kumar and Agrawal (2020), similar challenges identified by other researchers were found at every stage of the waste management life cycle, ranging from the initial collection to its subsequent treatment and final disposal (Kumar & Agrawal, 2020). Among SSA countries, similar poor MSWM practices have been reported. For instance, in Ghana, concern has been raised about the waste collection process, predominantly done through communal container collections, kerbside and house-to-house Collection services based on contractual and franchise agreements between agencies and private companies (Asare & Frimpong, 2013).

On a franchise basis, households and business outlets are charged, and the waste is collected from registered premises weekly, whereas, on a contractual basis, waste contractors are paid by the municipal authorities to perform communal container collection daily (Asare & Frimpong, 2013). Despite these arrangements, which improved waste collection rates, Lissah et al. (2020) note that there existed issues with waste collection and a low sense of responsibility among residents. Furthermore, various researchers have also reported challenges with payment for waste services in developing countries (Alabi, 2021; Boateng *et al*., 2019; Mukama *et al*.,2016). In a waste management study by Mukama *et al*. (2016), the authors highlighted deplorable MSWM practices in Uganda, especially in slums where inadequate sanitation, inaccessibility, and high costs were identified as significant barriers to effective MSWM. Waste storage and disposal practices in the slums were reported to be unsatisfactory, with minimal separation and composting practices.

Ssemugabo et al. (2020) examined public awareness and attitudes towards SWM in Uganda. Their findings highlighted that inadequate knowledge of sustainable waste management practices and a lack of understanding of individual responsibilities contribute to improper waste management practices. However, the participants in their study showed a high willingness to participate in SWM practices such as waste separation and composting. The study's results highlight the significance of a collaborative approach involving governmental authorities, private organisations, and the general public in fostering and advancing SWM through knowledge sharing and education. On the contrary, some researchers have reported that other developing Asian countries, including Malaysia, are progressing towards implementing SWM systems. According to Yong *et al*. (2019), although Malaysia still employs non-sanitary landfills on a limited scale, the recycling industry in the country continues to flourish. However, it was noted by the authors that recycling in Malaysia is primarily performed by the informal sector, which often operates in unsafe conditions and causes the disease to spread. Despite the formidable challenges in some developing countries highlighted earlier, Malaysia's increased recycling rates show that sustainability can be improved by forging synergistic partnerships and involving citizens in waste management initiatives.

2.3.1. Municipal Solid Waste Management in Nigeria

Numerous studies have been conducted to evaluate various facets of solid waste management in Nigeria (Aderoju, 2020; Duru *et al*., 2019; Ezeah & Roberts, 2012; Faniran *et al*., 2017; Joseph *et al*., 2020; Kadafa, 2017; Ike *et al*., 2018; Marafa & Magami, 2019; Nnaji, 2015; Ola & Suleiman, 2022; Umar *et al*., 2022). While only a limited number of these studies have achieved a national scope, the insights gleaned from most of these investigations possess significant transferability and relevance to other regions within the country (Ezeah & Roberts, 2012; Nnaji, 2015).

Despite being widely regarded as the giant of Africa (Bala & Tar, 2021), these studies have shown that Nigeria faces waste management challenges similar to other developing countries. According to most studies, the increasing MSW is influenced mainly by a growing population, globalisation, industrialisation, and urbanisation (Nnaji, 2015; Kazaure, 2016; Kadafa, 2017). While the MSWM challenges in Nigeria have persisted for a considerable period, spanning many years, they continue to present an enduring and complex challenge. According to Nnaji (2015), the global recognition of the implication of MSW on socio-economic development, public health, environmental preservation, and climate change has propelled the Nigerian government to appreciate the importance of modern technologies and innovations in dealing with MSW. Nnaji (2015) explains that this does not mean the Nigerian government has not made efforts in the past. However, the criticism is that the different strategies and inventions have failed to yield substantial outcomes.

Harmful practices like open dumping (Figure 2.2) remain a primary challenge in most major Nigerian cities as waste is disposed of on roadsides and water channels (Raimi *et al.,* 2019; Yusuf *et al*., 2019). According to various researchers, Nigeria’s urban cities are not exempted. An example is given by Kadafa (2017), who noted that in Nigeria’s prized capital city, Abuja, the open dumps tend to increase as one moves from the upper-class areas to the lower-class areas within the city. Similarly, in Lagos, Nigeria's most populous state previously serving as the country's capital, open dumps are spread in most parts of the city and are located based on convenience (Seriki-Mosadolorun, 2022).

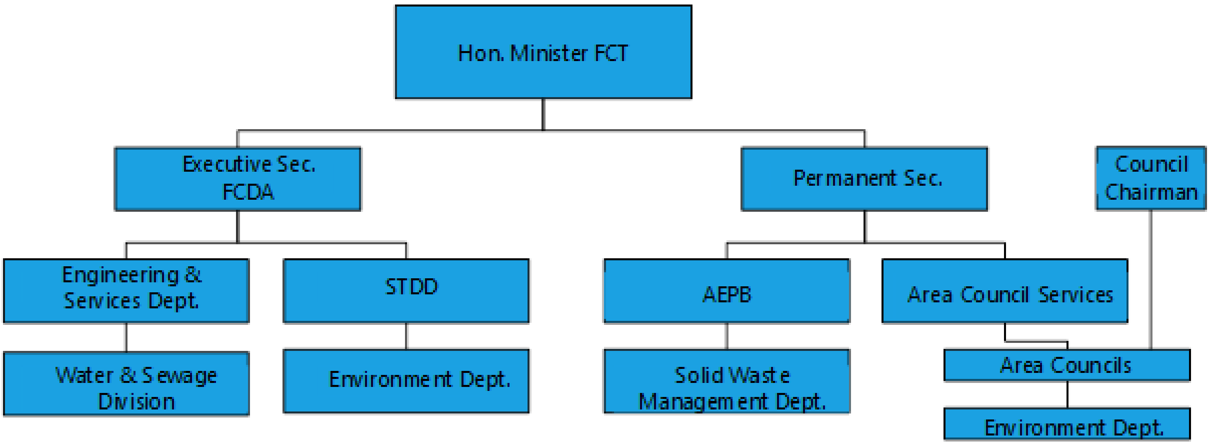
Figure 0.4 *Open Dumping on a road in Nigeria*

(*Note*: from Salami, 2018)

Furthermore, although waste collection has a higher rate within urban cities like Lagos and Abuja, the average waste collection rates of combined cities in Nigeria are notably low, with only 25-40% of waste being collected for disposal (Hammed *et al*., 2016; Amusan *et al*., 2018). Considering that waste collection is one of the most common services provided at the municipal level (Kasza *et al*., 2018), the rates from Nigerian cities are clear indicators of weak MSWM systems. In many Nigerian cities, municipal agencies are responsible for waste collection. For example, in Lagos state, the Lagos State Waste Management Authority (LAWMA) oversees waste collection and disposal, same as in Rivers State by the Rivers State Waste Management Agency (RIWAMA), the Kaduna State Environmental Protection Agency (KEPA) in Kaduna, and the Anambra State Environmental Protection Agency in Anambra to mention a few. However, these agencies often grapple with the challenge of effectively managing the escalating volumes of waste, necessitating implementing alternative approaches to enhance the system (Abur *et al*., 2014; Amusan *et al*., 2018; Joseph *et al*., 2022).

Focusing on Abuja, the administration of the FCT is overseen by the FCT's Honourable Minister, who is responsible for supervising the operations of various secretariats, departments, and agencies within the FCT (see Figure 2.3). This oversight is facilitated through the Permanent Secretary and the Executive Secretary. Within the FCT, the Department of Engineering Services under the Federal Capital Development Authority (FCDA) is a technical body responsible for planning, designing, and overseeing solid waste treatment facilities (JICA, 2018). Waste management within the metropolis is the primary responsibility of the Abuja Environmental Protection Board (AEPB). The establishment of the Abuja Environmental Protection Board (AEPB) was formalised through the enactment of Abuja Environmental Protection Board Decree No. 10 of 1997, outlining a comprehensive set of aims and objectives to guide its operations (Ezeah & Roberts, 2012).

Figure 0.5 *Organisational Structure related to MSWM in Abuja*



Not. Adapted from JICA, 2018

One of the AEPB's primary mandates is to ensure strict compliance with all environmental laws and regulations; this encompasses addressing various forms of environmental degradation and nuisances, thereby promoting a cleaner and healthier environment within the FCT. However, due to rapid urbanisation in the city, waste quantities swiftly increased, and the agency struggled to cope with its duties (Kadafa, 2017; Ogwueleka, 2013; Olukanni & Nwafor, 2019). In response to this pressing need for improvement, PPP arrangements were introduced in Abuja and adopted by other parts of the country. This strategic shift, as highlighted by Adama (2012), is intended to capitalise on the synergistic strengths of both the public and private sectors to optimise waste management practices. The initiative aimed to address the mounting waste accumulation and elevate the overall efficiency and sustainability of waste collection and disposal processes, predominantly door-to-door collection and disposal at open landfills; this increased the number of waste collection vehicles and other infrastructure, showing a positive outlook for the Nigerian waste management system (Olukanni & Nwafor, 2019).

Despite these efforts, Olukanni and Nwafor (2019) report that not enough changes have emanated in the system, as indications show that the infrastructural developments are not parallel to the population increase and waste quantities. Furthermore, Ogwueleka and Naveen (2021) argue that the failures of the waste agencies and private companies may explain the informal sector's increasing waste collection activities. According to Ogwueleka and Naveen (2021), informal waste pickers are at the helm of recycling, which is rarely practised at the household level; this indicates that informal waste pickers contribute significantly to recycling processes, acting as key agents in the overall waste management ecosystem. The lack of recycling within households is corroborated by Ayodele *et al*. (2018), Hammed *et al*. (2018) and Sridhar and Hammed (2014), who all agreed that recycling and waste segregation are rarely practised among households in Nigeria.

Another challenge highlighted by researchers that may explain the decline in the performance of private companies in Nigerian cities like Abuja is the lack of willingness to pay for waste services. Although contrasting results are found in some cities, as some researchers indicate that most residents are willing to pay, this is not always the case in reality (Alabi, 2021; Boateng *et al*., 2019). An indication of self-reporting bias perhaps exists. For example, a study by Adepoju and Salimonu (2010) and reported by Nwosu *et al*. (2018) found that the majority of the residents (87%) in Osun state were willing to pay for waste services. Similar high positive results towards payments were reported by Adebo and Ajewole (2012) and Oyawole *et al*.(2016) in Ekiti and South Eastern Nigeria, respectively. However, Olukanni and Nwafor (2019) argue that residents' refusal to pay for waste services is a primary factor in why private companies are struggling, thus indicating the gap between the willingness to pay and the act of making payment.

While such contrasting findings emphasise the transcending nature of waste management challenges in various cities, they also call for more comprehensive data collection methods in research to examine the true nature of these challenges. Furthermore, the complexity of these challenges is exacerbated by the high urbanisation rates, which make frequent evaluations of the existing waste management systems necessary. The discussions presented in this section show that the MSWM challenges in Nigeria and developing countries are similar, encompassing all aspects of standard MSWM activities. It has shown within the waste management trail that there are challenges with waste collection, indiscriminate dumping, lack of recycling and segregation, and unwillingness to pay for waste services, among other challenges. Therefore, providing a sustainable and effective MSWM that is fit for purpose requires a solid understanding of these aspects, from characterisation and composition, generation, collection and storage, policies, and regulations, to a particular understanding of the stakeholders involved. Furthermore, it is necessary to understand the barriers to SWM that explain the prevalence of these challenges in developing countries.

2.4. Municipal Solid Waste Generation in Nigeria

In Nigeria, MSW is generated daily, with the sources mostly grouped into household or domestic, industrial, commercial, and institutional waste (Aboje *et al*., 2014; Ogwueleka, 2013; Olukanni & Mnenga, 2015). Though there is no substantial data on the MSW generation, it has however been estimated that the annual generation of MSW is 32 million tonnes and a daily rate of 0.44kg-0.66kg/capita/day (Aliu *et al*., 2014; Olukanni & Mnenga, 2015). Though this information can be criticised for not being current, the lack of up-to-date data in Nigeria makes the challenge of estimating MSW generation a persisting case. Nonetheless, individual studies report waste generation in different cities and regions nationwide. For example, Nnaji *et al*. (2013) calculated Bauchi's solid waste generation rate as 0.31 kg/capita/day. In contrast, Audu *et al*. (2013) arrived at a 0.86 kg/capita/day figure for the same city. Similarly, Bichi and Amatobi (2013) approximated the rate as 0.31 for Kano, while Oumarou *et al*. (2012) derived a contrasting value of 0.81 kg/capita/day for the same city.

Furthermore, Oumaro *et al*.(2012) reported 0.81 kg/capita/day in Maiduguri. Comparing these findings with those of Bichi and Amatobi (2013), Maiduguri, a smaller town, would seem to generate more waste than Kano – a far larger state; this contrasts with the popular view in the literature that urban centres with larger populations generate more waste (Nnaji, 2015; Yusuf *et al.,* 2017). Regardless, the difference in sample size between both studies could explain the perceived deviation from the norm. Also, critical factors identified to influence the volume of the MSW stream include the method of research, time of the year or season at which the study was conducted, sources of data and the research coverage (Abur *et al.,* 2014; Afuno & Rabiu, 2017; Wahab & Ola, 2018).

A study conducted in 2018 by the Japan International Corporation Agency (JICA) in Abuja reported 0.50kg/capita/day within the city; this is a far cry from the 0.634 reported by Ogwueleka in 2013. Considering the rate of development and economic appreciation Abuja has undergone over the years, it is expected that waste generation per capita would increase rather than decrease, as posited by Hoornweg and Bhada-Tata (2012). Without viable national data, this thesis adopts the estimation for waste generation provided in Table 2.1. It is important to note that the figures are based on Nigeria's last national census in 2006, and populations and other dynamics have since changed.

Table 0.1 *MSW Generation for Cities in the Six Geopolitical Zones in Nigeria*

Urban City	Population (2006 Census)	Waste Generation Kg/pers/day	Waste Generation (ton per month)	Waste Generation density (kg/m^3)
South West				
Lagos	8,029,200	0.63	255,556	294
Ibadan	307,840	0.51	135,391	330
Ado-Ekiti	241,200	0.71	9.518	-
Akure	369,700	0.54	-	-
Abeokuta	529,700	0.66	-	-
South East				
Nsukka	100,700	0.44	12,000	370
Onitsha	509,500	0.53	84,137	310
Aba	784,500	0.46	236,703	-
South South				
Port Harcourt	1,053,900	0.60	117,825	300
Warri	500,900	-	66,721	-
Uyo	102,400	-	20,923	-
North Central				
Abuja	159,900	0.634	14,758	280
Makurdi	249,000	0.48	24,242	340
Illorin	756.400	-	-	0.43
North West				
Kano	3,248,700	0.56	156,676	290
Kaduna	1,458,900	0.58	114,443	320
North East				
Maiduguri	971,700	-	850,000	-

(Source: Ogwueleka, 2009; Ogwueleka, 2012)

2.5. Municipal Solid Waste Composition in Nigeria

An essential component in formulating an MSWM system is a comprehensive understanding of waste composition within the municipality; this involves a detailed analysis of the quantities and various types of waste the community generates. Such an understanding provides invaluable insights into the unique waste profile of the area, serving as a foundational pillar for efficient waste management planning and decision-making. (Babatunde *et al.* 2013: Afuno & Rabiu 2017). MSW has been established to exhibit variations based on geographical location and consumer behaviours within a specific locality (Nnaji, 2015). These distinctive factors contribute to the unique composition and characteristics of waste generated in different regions, making waste management strategies inherently localised and context-specific. (Abduli *et al.* 2011; Nnaji, 2015, Ogwueleka, 2013).

According to Khan *et al*. (2022), understanding waste composition and characteristics determines the appropriate technology for developing MSWM strategies that meet local requirements. Certain factors have also been highlighted to influence the composition and characterisation of MSW. They include source location, inequality in socio-economic status, seasonal and weather conditions, the nature of business in the area, and cultural obligations (Abur *et al*., 2014). MSW in low-income areas of Nigerian cities is primarily organic, and its volume increases exponentially during festive seasons when there is a high consumption of food and drinks (Abur *et al.,* 2014; Afuno & Rabiu, 2017).

Whilst there is insufficient data on the general data on MSW characterisation and composition in Nigeria, several studies have been conducted in different cities and regions of the country (Abah & Ohimain, 2010; Lade *et al*., 2012; Babatunde *et al.,* 2013; Abur *et al.,* 2014; Afuno & Rabiu, 2017; Ezeudu *et al*., 2019; Ugwu *et al*., 2020). Lade *et al.* (2012) examined generated MSW in the Bodija market, Ibadan, which is characterised mainly by nylon. The commercial activities within the market environments can explain this. Also, Babatunde *et al.* (2013) examined the composition of MSW in three LGAs in Rivers State and characterised MSW to include primarily organic waste, followed by nylon (plastic bags) and paper. Others identified

MSW composition as plastics, metal, glass, and others. Abur *et al.* (2014) reported that more than 56 % of MSW generated in Abuja is made up of biodegradable matter that can be composited rather than disposed of and comprised mainly of fabrics, food/putrescible, glass/ceramics, metals, paper, plastics, rubbers, and other materials. A summary of waste composition from some Nigerian cities reported by Harir *et al*. (2015) is presented in Table 2.2.

Table 0.2 *Waste Composition Summary from Various Cities in Nigeria*

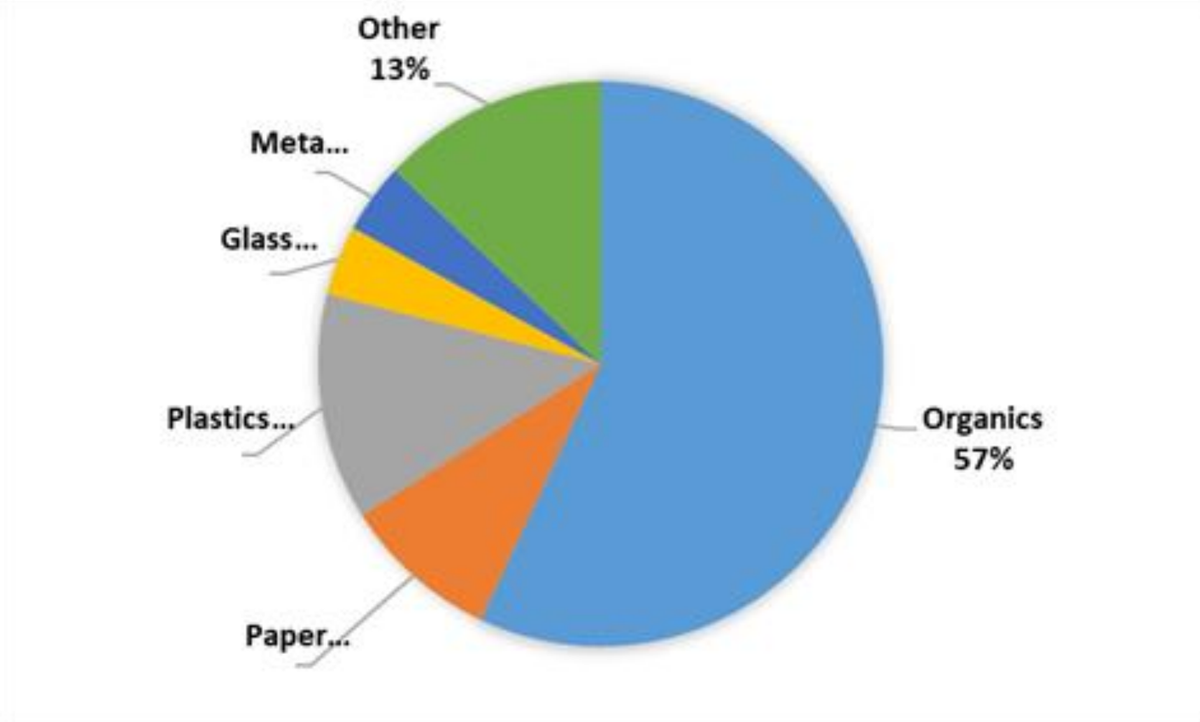
City	Organic (%)	Paper (%)	Plastic (%)	Glass (%)	Metal (%)	Textile & Leather (%)	Others (%)
Makurdi	52.2	12.3	8.2	3.6	7.1	2.5	14
Abuja	58.5	8	11.3	4.8	3.1	-	0.2
Maiduguri	25.8	7.5	18.1	4.3	9.1	3.9	31.3
Kano	43	17	4	2	5	7	22
Onitsha	30.7	23.1	9.2	9.2	6.2	6.2	15.4
Nsukka	56	13.8	8.4	2.5	6.8	3.1	9.4
Ibadan	76	6.6	4	0.6	2.5	1.4	8.9
Lagos	56	14	4	3	4	-	19

(*Note*: from Harir *et al*., 2015)

Also, Afuno & Rabiu (2017) conducted characteristics and composition analysis of MSW in four major dumpsites servicing eight metropolitan local government areas in Kano and identified ten materials in the MSW, including light and heavy plastics, organics, fabric, paper, metal, glass, bone, and other materials including wood. Orhorhoro *et al*. (2017) examined the MSW generated by 100 Sapele, Delta State households. They reported the composition of the MSW to include organic or food waste (75%), plastic/rubber waste (10%), paper waste (6%), glass waste (4%), metal waste (3%), and other waste (2%). Adeniran *et al*. (2017) gathered data from the University of Lagos, Akoka campus. They characterised the composition of MSW as polythene bags 24% (7.73 tonnes per day), paper and organic matter 15% (4.83 tonnes per day) respectively, plastic 9% (2.90 tonnes per day), inert materials 8% (2.58 tonnes per day), sanitary 7% (2.25 tonnes per day), textile 7% (2.25 tonnes per day), others 6% (1.93 tonnes per day), leather 4% (1.29 tonnes per day), metals 3% (0.97 tonnes per day), and glass 2% (0.64 tonnes per day).

Ugwu *et al.* (2020) divided their study area, which was the Federal University Campus, Nsukka, Enugu State into four parts: commercially dominated, academically dominated, staff and hostel dominated and characterised MSW to include mostly organic (34%), polythene (32%), paper (14%), plastic (9%) and others (11% – including glass/bottle, metal, textiles/leather/wood, e-waste, medical, sanitary, and polystyrene food packs). Organic waste predominantly originated from areas primarily occupied by staff, hostels, and commercial establishments. On the other hand, paper waste was primarily generated in areas dominated by academic classrooms. In terms of polythene, all areas contributed immensely to the generated waste. The results from these investigations are in accordance with existing literature, which indicates that the composition of MSW in developing countries is predominantly organic (Nnaji, 2015; Yusuf *et al*., 2017). This trend also mirrors the waste composition observed in Sub-Saharan African (SSA) nations (Figure 2.4).

Figure 0.6 *Waste Composition in SSA*



Note: Adapted from Godfrey *et al*., 2019

Nevertheless, it is crucial to recognise that as urbanisation and economic prosperity advance within the country, the utilisation of inorganic materials, including paper, plastics, and metals, tends to rise. Simultaneously, the proportion of organic waste and inert materials in the waste stream generally experiences a relative decrease (Kaza *et al*., 2018; Sharma & Jain, 2020).

2.6. Factors Influencing Waste Generation and Composition

Waste generation and composition are complex processes influenced by many interconnected factors. The general discussion also has already pointed to the fact that population growth positively affects waste generation. Understanding these factors generally is crucial for designing effective waste management strategies that address the unique challenges of each locality. Several vital factors significantly shape waste generation and composition, encompassing societal and environmental dimensions (Trang *et al*., 2017).

Among the key factors is socioeconomic status, a pivotal determinant of waste generation (Adeleke *et al*., 2021). Higher-income households produce more waste due to increased purchasing power and consumption levels (Ekwule *et al*., 2020). However, Ogwueleka (2013) argues that this varies depending on consumption habits in some regions or areas. An example is a study by Trang *et al*. (2017), which reported a negative correlation between income and waste generation in Vietnam. Furthermore, a study by Khan et al. (2016) found little difference in waste composition among socioeconomic groups, particularly for plastics only. Other factors, including the period of study and methods used, may influence such findings. Similarly, consumer choices regarding products, packaging, and disposable items significantly influence the composition of the waste stream. For example, a preference for single-use plastics or convenience-oriented products, common among high-income earners, can contribute to higher quantities of non-recyclable waste.

Also, Trang et al. (2017) also noted that cultural and lifestyle factors influence waste generation patterns. Cultural norms and practices related to food consumption, religious rituals, and festivities can impact the types and quantities of waste generated. Additionally, societal attitudes towards recycling and waste reduction play a role in shaping waste composition. Communities with a strong recycling culture may exhibit lower proportions of recyclable materials in the waste stream (Knickmeyer, 2020).

Furthermore, Kamran *et al*. (2015) found a statistically significant difference in waste composition among socioeconomic groups and seasons in India. According to the authors, climate influences waste composition through seasonal variations, affecting the amount of organic waste generated, as regions with different agricultural practices or industrial activities may produce distinct types of waste. However, in the study on seasonal variation of waste composition in Abuja by Ezeah and Roberts (2012), it was noted that climatic conditions did not affect waste composition, although changes were notable among socioeconomic groups; this furthers the argument that some factors may vary depending on regions. Also, in the study by Ezeah and Roberts, it is worth noting that only the Garki District was delineated into the various socioeconomic groups and may not accurately represent the city's economic status. While other factors, such as legislation, can influence waste generation and composition in communities (Thakur & Kumar, 2022), this study hinges on the critical socioeconomic indicator: income level.

2.7. MSW Collection and Disposal in Nigeria

Another crucial stage in MSWM is collection and disposal. In Nigeria, the MSWM system has long been plagued by poor and unhygienic waste collection and disposal (Amusan *et al.,* 2018). Several factors have been attributed to this, ranging from the inability of waste management authorities to collect waste, poor infrastructural facilities, and a poor road network to financial constraints and the unwillingness of the public to contribute to sustainable waste management practices through financial and moral commitments (Hammed *et al.,* 2016; Olukanni & Nwafor, 2019).

With increasing awareness of the burden of MSW in recent years, most MSWM authorities are now encouraging households to bag their MSW before depositing it in bins or specific locations (Nduneseokwu *et al.,* 2017; Ezeudu & Ezeudu, 2019). Also, some cities like Lagos encourage residents to sort their waste at source by providing different types of waste bins for different MSW categories, such as organic and recyclables (Adeniran *et al*., 2017).

Generally, waste collection in Nigeria is divided mainly into formal and informal processes. The formal process includes waste management authorities like AEPB in Abuja, partnering the private sector firms through PPP arrangements actively collecting MSW from residential or industrial areas with huge vehicles to designated disposal sites (Hammed *et al.,* 2016; Amusan *et al.,* 2018; Wahab & Ola, 2018). In contrast, informal waste collectors employ unconventional means such as wheelbarrows, carts, head pans or baskets to collect and transport MSW at a set price (Ogwueleka & Naveen, 2021; Wahab & Ola, 2018). The formal process provides a more capital-intensive venture, but its operation has been largely unsuccessful in Nigeria (Ogwueleka, 2009; Wahab & Ola, 2018). Aside from the financial constraint, the formal waste collection operations have been hampered by the poor road network and terrain, which obstruct the movement of these big vehicles (Nduneseokwu *et al.,* 2017; Ezeudu & Ezeudu, 2019). Extreme traffic congestion during the day and night insecurity are other factors that hamper formal operations (Aliu *et al.*, 2014; Olukanni *et al.*, 2018; Wahab & Ola, 2018).

Generally, landfills stand as the prevailing method for waste disposal, yet the absence of engineered landfill systems in Nigeria fosters the use of open dumpsites for waste management (Ogwueleka, 2013; Orhorhoro & Oghoghorie, 2019). Most landfills are hosts to waste pickers searching for recyclables, as shown in Figure 2.5.

Figure 0.7 *Informal Waste Pickers operating at Gosa Landfill Abuja*

(*Note*: from AEPB 2021)

Similarly, given the absence of intermediate treatment measures in Abuja, the sole destination for waste generated within the municipality is the Gosa landfill managed by AEPB (JICA, 2018; Nwosu *et al*., 2016). The AEPB encounters a significant challenge in managing the Gosa landfill due to the indiscriminate fly-tipping of waste, particularly during the rainy season. This issue arises from the inaccessibility of the main tipping point entrance, resulting in the landfill being closed during such periods (Ayuba *et al*., 2013; Nwosu *et al*., 2016).

2.8. Exploration of sustainability and waste management challenges in Nigerian cities

Exploring sustainability and waste management challenges in urban areas is a critical area of academic research, particularly as cities face increasing waste generation and environmental pressures (World Bank, 2021). The following sections summarise key findings from recent literature on this topic.

2.8.1. Challenges in Waste Management

Infrastructure and Funding Issues: Many cities, especially in developing countries, struggle with inadequate infrastructure for waste collection and segregation; this often leads to improper waste disposal methods, exacerbating environmental pollution and public health issues.

Informal Waste Sector: The informal sector plays a significant role in waste management systems, particularly in developing nations. Approximately 90% of residual waste is often dumped rather than properly managed, highlighting the need for more formalised systems to integrate informal waste pickers into the overall waste management strategy.

Urbanisation and Population Growth: Rapid urbanisation and population growth are significant contributors to the increasing volume of municipal solid waste (MSW). This surge places immense pressure on existing waste management systems, which are often ill-equipped to handle the demand (Miller *et al*., 2020).

Economic Constraints: The high costs associated with waste management and limited municipal budgets hinder effective waste management strategies. Many urban local bodies (ULBs) lack the financial resources to implement sustainable practices.

2.8.2. Opportunities for Improvement

Waste Segregation and Resource Recovery: There is a growing emphasis on waste segregation at the source and the use of specialised facilities for recycling. This approach reduces the volume of waste sent to landfills and promotes resource recovery, which can be economically beneficial.

Investment in Technology: The potential for energy generation from waste, such as methane extraction from landfills or waste-to-energy technologies, presents significant opportunities. However, the success of these initiatives often depends on the availability of qualified professionals and engineers to implement them effectively (Miller *et al*., 2020).

Integrated Sustainable Waste Management (ISWM): The ISWM model offers a comprehensive approach to analysing and improving waste management systems. It emphasises the importance of stakeholder involvement and the need for a multi-dimensional understanding of waste management challenges.

International Collaboration: Initiatives such as seminars and workshops organised by international bodies can foster knowledge exchange and collaborative strategies for sustainable waste management, particularly in regions like South Asia.

The literature indicates that while significant challenges exist in urban waste management, there are also numerous opportunities for improvement through better infrastructure, stakeholder engagement, and innovative technologies. Addressing these challenges requires a concerted effort from municipal authorities, the private sector, and communities to develop sustainable waste management practices that can adapt to the evolving needs of urban populations (Kadafa, 2017).

2.9. MSWM Policies and Regulations in Nigeria

The challenges of implementing a sustainable MSWM system in Nigeria can be pinned down to a lack of adequate policies relating to waste management (Abila & Kantola, 2013; Sridhar *et al*., 2017). Where these policies abide, a significant challenge is implementation (Ahmed *et al*., 2022). Abila and Kantola (2013) echoed this in their study, arguing that policies and regulatory frameworks have never been the primary concern in Nigeria, but the political will needed to implement and administer these policies has been the challenge. Different legislations have been enacted in Nigeria to address public health and environmental sanitation, but these legislations have not yielded much results.

The establishment of the Federal Environmental Protection Agency (FEPA) in 1988 can be argued as the foremost effort by the Nigerian government to combat environmental pollution and other public health-related issues (Abila & Kantola, 2013; Sridhar *et al.,* 2017). The decree allowed FEPA the power to issue guidelines and standards to reduce and control the various forms of environmental pollution (Onu *et al*., 2012; Sridhar *et al.,* 2017). In agreement with the FEPA Act, every state and local government in Nigeria can enact laws ensuring environmental protection within their jurisdiction and constitute an environmental protection unit within such jurisdiction (Onu *et al.,* 2012). FEPA was later absorbed by the Ministry of Environment when it was created in June 1999. When it comes to MSWM, three key policies and regulations exist (JICA, 2018) as shown in Table

Table 0.3 *Key Policies/Regulations Governing MSWM in Nigeria*

Policy/Regulation	**Description**
National Policy on the Environment 2016	The Policy aims to define a framework for environmental governance in Nigeria.
National Environmental Sanitation Policy (2005)	This policy document defines environmental sanitation as applying principles and practices to create and maintain healthful and hygienic environmental conditions. This approach's primary objectives are to enhance public health and welfare, elevate the overall quality of life, and contribute to the sustainability of the environment.
National Environmental (Sanitation and Wastes Control) Regulations, S. I. No. 28 of 2009	This regulation provides the legal framework for adopting sustainable and environmentally friendly practices in environmental sanitation and waste management to minimise pollution.

Furthermore, a National Policy on Solid Waste Management was prepared and is awaiting approval by the responsible authorities (JICA, 2018). The roadmap for waste management in Nigeria in the coming years is documented within the draft document. The key policy statement is as follows:

> *"Solid waste shall be harnessed as a resource to promote economic growth and managed to improve the quality of human and environmental health" (FEPA 2018, s. 3.1)*

This statement emphasises Nigeria's interest in adopting sustainable energy recovery from MSW. It is also supported in Section 1.3, which outlines the government's interest in scaling up the introduction of WtE in the country (FEPA 2018). The overarching aim of the policies and regulations is to improve waste management practices and awareness (Danbaba *et al*., 2016). An essential component of the monthly sanitation exercise is the compulsory participation of residents. During these designated days, residents are required to engage in sanitation activities, such as cleaning their surroundings, properly disposing of waste, and contributing to the overall tidiness of the city. According to Olowoporopku (2017), this participatory approach fosters a sense of responsibility among residents and instils a positive culture towards waste management. On the contrary, Nwufo (2010) criticised the laws, policies, and regulations for focusing on punishing defaulters (by instituting fines) but not specifying any incentives for those who comply.

2.10. Stakeholder Involvement in Nigerian MSWM

Having previously examined the Nigerian government's policy formulation and regulatory role, this section now focuses on exploring the engagement of various stakeholders in MSWM, including formal and informal actors, non-governmental organisations (NGOs), and public participation.

2.10.1. Public Participation in MSWM in Nigeria

Public participation plays a pivotal role in SWM. It is recognised as a crucial component that aligns with the principles of environmental sustainability and community well-being. In recent years, there has been a growing emphasis on involving the public in waste management processes, decision-making, and awareness campaigns due to its lack, particularly in developing countries (Danbaba *et al*., 2017). This lack of public consultation in decision-making has contributed to a lack of interest in environmental initiatives. The literature review observed that not many studies in Nigeria have focused on the issue of public participation, perhaps summarising the disinterest. Public participation can be assessed based on behaviours towards recycling and segregation, which have already been established as inadequate in Nigeria during the discussions in the previous sections (Salsabila *et al*., 2021).

This study focuses on public participation in strategies developed by the government to improve waste management and sanitation. As discussed in the preceding section, the National Environmental Sanitation Policy 2005 sets aside regulations mandating the public to participate in sanitation and waste management exercises on a particular day of the month. Aside from the policy being criticised as a quick-fix strategy, Olowoporopku (2017) and Danbaba *et al*. (2017) posited the lack of public interest and participation in the exercise. Furthermore, the authors argue that the low participation rates and negative perceptions suggest a disconnect between the policy implementation and the expectations and needs of the residents. Another point raised on the issue is that setting out one day a month for the purpose is not an ideal way to improve participation. All the parameters by which public participation in Nigeria can be assessed tend to indicate a lack of commitment to waste management activities.

2.10.1.1. Factors Influencing Public Participation in Waste Management

Some researchers have identified how factors such as socioeconomic status, access to sanitation facilities, cultural norms, and community resources may influence participation in waste management (Amasuomo *et al*., 2015; Babayemi & Dauda, 2010; Jereme *et al*., 2021; Oyelakin *et al*., 2022). In a study on household participation in a sustainable food waste management strategy in Malaysia, Jereme *et al*. (2021) found that respondents with higher education, those on government jobs, those with small family sizes and those ethnicities have significant impacts on the respondents' behaviour towards participation in sustainable food waste management program. These findings imply that the level of education, employment status, household size and cultural norms can influence public participation. Also, one of the few studies on public participation in Abuja, Nigeria, by Amasuomo *et al*. (2015), reported that public participation can be hinged on access to waste disposal facilities. Based on these findings, it is assumed that these factors can influence public participation in Nigeria's environmental sanitation strategy.

2.10.2. Private Sector Involvement in MSWM in Nigeria

Generally, in Nigeria, the private sector is involved in a vast range of activities in MSWM, from waste collection, storage, recovery, incineration, and landfilling operations (Agboje et al., 2014; Olukanni & Nwafor, 2019). These cooperate entities entered into formal agreements with the government to participate in the different stages of MSWM at a chargeable fee to the municipalities (Adama, 2012; Agboje *et al.,* 2014). Since their introduction into the system, there have been some improvements, particularly in waste collection, although collection rates are still far below what was expected (Olukanni & Nwafor, 2019). Interestingly, concerns have been raised that these firms often prioritise profit-making in some chatters, potentially leading to elevated service costs that could burden the general public and exacerbate the waste management challenge (OECD, 2013; Arbulu *et al*., 2016).

Nevertheless, the PPPs have been encouraged by many states and local governments in Nigeria as alternatives to complete privatisation of the sector in view to mitigating the financial and infrastructure challenges of the MSWM sector (Aleluia & Chomchuen, 2015; Olukanni & Nwafor, 2019). Examples of such partnerships are in Lagos and Abuja, where the waste agencies work cohesively with these private companies to deliver improved MSWM services. Following the initial success, other states followed this model, engaging with the private sector to improve the infrastructure by purchasing compact trucks and street sweepers (Olukanni & Nwafor, 2019).

The activities of the PPPs have been judged to have improved the MSWM service delivery by injecting the finances necessary to improve the infrastructures and the vehicles for waste collection and transportation (Storey *et al.,* 2015; Olukanni & Nwafor, 2019). However, some resident households' unwillingness to pay for MSWM services has been cited as a constraint to the sustained performance of MSWM in Nigeria (Agboje *et al.,* 2014). On the other hand, Olukanni and Nwafor (2019) attributed the private firms' lack of commitment to the continued inefficiency of the MSWM services in Nigeria, which has resulted in service gaps in the collection, treatment, and disposal of MSW.

2.10.3. Informal Sector Participation in MSWM in Nigeria

The informal sector includes scavengers and waste pickers who are unregistered and often conduct unregulated activities within the MSWM sector (Ogwueleka & Naveen, 2021; Nzeadibe & Ejike-Alieji, 2020). These individuals engage in scavenging activities at landfill sites to gather materials for personal use or resale, often as part of recycling efforts. This practice is prevalent in numerous Nigerian urban areas, and there seems to be an increasing recognition and tolerance of these informal actors among the urban population (Ola & Suleiman, 2022). According to Ogweleka and Naveen (2021), the informal actors engage in their activities with little or no concern for their health or the need to adhere to health and safety procedures. However, they are known to play a significant role in MSWM activities in Nigeria, from waste collection to transportation, sorting, reuse, recycling material recovery and final disposal (Akanle & Shittu, 2018). They perform these activities without adhering to safety measures; nonetheless, they contribute massively to MSW reduction and provide a source of income earning (Mohammad *et al.*, 2015; Ola & Suleiman, 2022). On the contrary, rather than encourage and build on their activities, it has been reported that in cities like Abuja, informal waste pickers are usually banned and, in some cases, their work equipment is seized (Imam *et al*., 2008; Joseph *et al*., 2020).

Figure 0.8 *Informal Waste Picker on Duty*

(*Note*; from Adanikin, 2020)

Increasing the activities of the informal waste pickers would not only provide economic value to the Nigerian government by way of reducing the cost and time required for administering MSW collection, transportation, and disposal (Agyemang *et al*., 2019) but also assist in stimulating grass root development, poverty alleviation and socio-environmental preservation (Mohammad *et al.,* 2015; Nzeadibe & Ejike-Alieji, 2020; Ogwueleka & Naveen, 2022). However, Ogwueleka and Naveen (2022) and Nzeadibe and Ejike-Alieji (2020) strongly criticised the Nigerian government for the absence of an inclusive MSWM policy that recognises the activities of the informal actors in the planning and implementation of MSWM strategies. The authors further went on to argue that by ignoring the informal sector, the policymakers and regulators of MSWM strategies lack the understanding of the underlying political economy of waste work, prejudicial attitude towards the informal economy on the part of elected officials who see little political capital or mileage to be gained from supporting the informal actors.

2.10.4. Non-governmental organizations (NGOs) Participation in MSWM

In the context of MSWM, NGOs frequently assume the role of intermediaries, facilitating collaboration between municipal authorities, private sector enterprises, and the general public to orchestrate educational initiatives and advocacy workshops. These actions aim to heighten awareness about adopting sustainable MSWM practices (Mbah & Nzeadibe, 2017). Despite their active engagement, NGOs have faced substantial criticism in recent times for their perceived inadequacy in adequately raising awareness or enhancing the capacity of the public regarding sustainable practices in MSWM (Adeyemi *et al*., 2020).

However, Salau *et al*. (2017) took a different perspective in analysing the criticism, arguing that the MSWM system features a public-private partnership model that relies heavily on the private sector for almost all of its MSWM initiatives living out other critical stakeholders like NGOs, thereby creating a deficient MSWM structure that undermines socio-economic development and stalling urban growth in terms of leveraging on extreme poverty reduction and creating social inclusiveness in the urban space. Overall, NGOs, through private funding, have shown commitment to improving waste management within communities in Nigeria, even when met with bottlenecks (Mbah & Nzeadibe, 2017).

2.11. Global challenges of waste management in the context of sustainability

Waste management remains a significant global challenge in the 21st century, with strong linkages to other global issues such as health, climate change, poverty reduction, food and resource security, and sustainable production and consumption. Despite progress, the world still faces significant challenges in developing practical and sustainable waste management systems (Ganda, 2020; Hoinaru *et al*., 2020). Many cities, especially in developing countries, struggle with inadequate waste collection, segregation, and disposal infrastructure; this often leads to improper waste management practices that exacerbate environmental pollution and public health issues. The surge in urban population and economic growth has resulted in increased municipal solid waste (MSW) generation per person, placing immense pressure on existing waste management systems. Current systems in many countries cannot cope with the growing volumes of waste. The informal sector plays a significant role in waste management, particularly in developing nations (Liddle, 2017). However, approximately 90% of residual waste is often dumped rather than properly managed, highlighting the need for more formalised systems that can integrate informal waste pickers.

The high costs associated with waste management, combined with limited municipal budgets, hinder the implementation of sustainable practices. Many local authorities lack the financial resources to invest in improved waste management infrastructure and technologies (Ogwueleka & Naveen, 2021). There is often a lack of emphasis on waste segregation at the source and the use of specialised facilities for recycling and resource recovery. Promoting these practices can reduce waste sent to landfills and promote a more circular economy. A comprehensive approach is needed to address these challenges and move towards more sustainable waste management; this includes investing in infrastructure, fostering stakeholder engagement, promoting waste segregation and recycling, and developing innovative technologies such as waste-to-energy facilities. Capacity building and training at all levels are crucial to successfully implementing sustainable waste management strategies.

2.12. Barriers to Sustainable Waste Management

Various researchers have assessed and categorised the barriers to sustainable waste management in different ways pertaining to the scope of their studies. More often than not, the context of these classifications often refers to the same factors. For example, in a study by Yukalang *et al*. (2017) that investigated the barriers to MSWM in Thailand, whose cities have similar urbanisation patterns like Abuja, the barriers influencing waste management were categorised into social-cultural, technical, financial, organisational, and legal-political barriers and population growth. This classification is similar to Guerrero *et al*. (2017), who examined barriers using financial, institutional, socio-cultural, environmental, legal, and technical parameters.

Furthermore, Ezeah and Roberts (2012) examined barriers to SWM in Abuja, including socio-economic, operational, institutional/regulatory, and physical/natural factors. Despite these different overarching classifications, the researchers discuss similar factors under these categories that hinder sustainable waste management in developing countries. Among these factors are the lack of environmental education, inadequate environmental budgets, poor policies and strategies, lack of infrastructure, increased waste generation, lack of publicity, lack of incentives, and unskilled labour. These researchers highlight in their discussions that municipalities and governments in developing countries, especially in SSA, must address the current poor state of MSWM systems by first understanding the barriers to effective waste management. The following sections integrate some of these barriers into three overarching themes.

2.12.1. Financial Barriers

The lack of funds or inadequate funding can pose a significant obstacle to establishing and sustaining efficient MSWM systems. The allocation of insufficient financial resources hampers the ability to construct or enhance MSWM systems (Yukalang *et al*., 2017). The World Bank estimates that around 20-50% of the environmental budgets in many developing country municipalities are allocated to MSWM. However, a substantial portion of urban waste remains uncollected, with less than 50% of the population being served in most developing countries (Lohri *et al*., 2014). Nevertheless, the argument raised by most researchers is that, in the first place, the budgets allocated for environmental purposes are insufficient. Although the challenge of underfunding in MSWM is multifaceted, encompassing issues such as budgets, refusal to pay for services, and mismanagement of public funds (Ezeah & Roberts, 2012; Hoinaru *et al*., 2020), its effect is felt in most aspects of the waste management system. For example, funding is required to improve infrastructure, like purchasing compactor trucks or providing public waste bins. Furthermore, strategies that involve training programmes are equally required. Hence, the lack of funding is considered an overarching barrier in MSWM (Hoinaru et al., 2020), which can give rise to technical and operational barriers.

2.12.2. Policies Governance and Institutional Barriers

Policy, governance, and institutional factors play pivotal roles in shaping MSWM systems worldwide. Developed countries like the EU member states and Japan have achieved successful waste management systems through robust policies and legislation, setting examples for emulation (Kaza *et al*., 2018). The collaboration between local and central governments is crucial in establishing functional MSWM systems, influenced by political dynamics and citizen involvement in policy-making (Konteh, 2009; Durgekar, 2016), and achieving sustainable MSWM systems in low-income countries hinges on harmonising policy, governance, institutional mechanisms, and resource allocation (Ezeah & Roberts, 2012).

In contrast, political instability and civil unrest, especially in SSA, complicate MSWM efforts, often diverting priorities away from sustainability (Yuklang *et al*., 2017). Political shifts and corruption can undermine long-term projects, leading to budget misallocation or abandonment (Ganda, 2020; Hoinaru *et al*., 2020). Scholars advocate for a shift towards good governance, emphasising collaboration among government, citizens, NGOs, and the private sector (Konteh, 2009; Bhuiyan, 2010). Poor governance and insufficient infrastructure, such as research institutions and freedom of information laws, hinder effective MSWM in low-income countries. Hoinaru et al.(2020) noted that political interests often supersede public welfare, impacting decision-making and hampering infrastructure development. Therefore, developing effective MSWM necessitates well-crafted policies and regulations and transparent communication and engagement with diverse community stakeholders (UNEP, 2019).

2.12.3. Socio-economic and Cultural Barriers

Effective MSWM systems are rooted in the prevailing behavioural patterns and attitudes influenced by the local cultural and social context (Agyemang *et al*., 2019). According to Wilson *et al*. (2013), in urban areas, the diversity of the population dramatically impacts the implementation of MSWM strategies; this implies that cities with high urbanisation rates face complex challenges in implementing SWM systems. As these urban areas attract people from diverse backgrounds seeking better opportunities and lifestyles, the resulting mixture of waste types and characteristics requires adaptable and robust waste management strategies. The economic circumstances of these migrants, who comprise a significant portion of the urban population, impact their capacity to engage with formal waste management services that may come at a cost. Their financial burdens often force them to seek more affordable alternatives, including using informal waste collection methods or improper disposal practices (Adama, 2012; Kadafa, 2017; Ogwueleka & Naveen, 2021). This affordability challenge then has a cascading effect on waste management systems.

Moreover, such individuals lack awareness and poor attitudes regarding waste, significantly impacting the MSWM, including storage, recycling, and waste reduction (Kwatra, 2014; Adekola *et al*., 2021). Hence, the lack of awareness or negative attitudes contributes to various challenges in MSWM. This improper waste handling, inadequate sorting, and the absence of recycling efforts can lead to increased contamination levels in the waste stream, thereby hindering efficient waste separation and recycling processes. Therefore, increasing public awareness through targeted education on MSWM can foster positive attitudes and safe practices (Okechukwu *et al*., 2012; Ojewale, 2014). However, Debrah *et al*., 2022) argue that most developing countries do not invest in environmental education. Without proper education and awareness campaigns, communities may not understand the environmental consequences of their actions, leading to improper waste disposal, pollution, and the exacerbation of waste management challenges (UNEP, 2019).

Overall, rapid urbanisation, socioeconomic inequalities, and insufficient amenities characterise developing countries, particularly in SSA, placing strain on MSWM systems (Konteh, 2009; Wilson & Velis, 2014). High-density, low-income settlements often lack adequate MSWM services and alternative waste disposal methods (Ezeah & Roberts, 2012)). Lack of space, inaccessible terrain, and inadequate infrastructure lead to poor waste management in such areas (Kadafa, 2017).

2.13. Social and governance challenges of solid waste management

The social and governance challenges of solid waste management (SWM) are significant and multifaceted, particularly in the context of rapid urbanisation and environmental sustainability. The academic discourse highlights several key issues that affect the effective management of solid waste, especially in developing countries (Adama, 2012; Alabi, 2021; Boateng *et al*., 2019; Kadafa, 2017).

2.13.1. Governance Challenges

a) **Lack of Prioritisation**: Local governments often do not give solid waste management the attention it deserves. This lack of prioritisation can result in inadequate policies, insufficient funding, and poor infrastructure, ultimately leading to ineffective waste management practices.

b) **Fragmented Governance Structures**: Many regions experience fragmented governance, where multiple agencies are involved in waste management without explicit coordination or accountability; this can lead to inefficiencies and gaps in service delivery, exacerbating waste management challenges.

c) **Public-Private Partnerships**: The private sector's involvement in waste management can be beneficial, but it also introduces governance challenges. Effective collaboration between public and private entities is essential to ensure equitable waste management services meet community needs. Poor governance arrangements can hinder these partnerships, leading to suboptimal outcomes.

d) **Regulatory Frameworks**: Inadequate or poorly enforced regulations can contribute to unsustainable waste management practices. Effective governance requires robust legal frameworks that facilitate compliance and accountability among waste management stakeholders.

e) **Community Engagement**: Successful waste management relies on community participation and awareness. However, many governance structures fail to engage local communities in decision-making, disconnecting waste management strategies and residents' needs (Adama, 2012).

2.13.2. Social Challenges

a) **Public Health Risks**: Poor waste management practices, particularly in marginalised communities, can have severe public health implications. Inadequate waste collection and disposal can lead to increased incidences of diseases, such as diarrhoea and respiratory infections, disproportionately affecting vulnerable populations.

b) **Environmental Justice**: The burden of inadequate waste management often falls on low-income and marginalised communities, leading to environmental injustice. These communities frequently face more significant pollution and health risks associated with poorly managed waste sites.

c) **Awareness and Education**: A significant challenge in solid waste management is the lack of public awareness regarding waste segregation, recycling, and the environmental impacts of waste. Educational initiatives foster community engagement and promote sustainable waste management practices (Kadafa, 2017).

d) **Cultural Attitudes**: Cultural perceptions of waste and cleanliness can influence management behaviours. In some societies, a stigma may be associated with waste collection and management, affecting individuals' willingness to participate in waste reduction and recycling initiatives.

The social and governance challenges of solid waste management are complex and interrelated. Effective governance mechanisms, community engagement, and public awareness are essential for addressing these challenges and improving waste management practices. As cities grow and face increasing waste generation, a comprehensive approach incorporating both social and governance dimensions will be critical for achieving sustainable solid waste management (Boateng *et al*., 2019). Addressing these challenges can improve public health, environmental sustainability, and overall quality of life in urban areas.

2.14. Models for Sustainable Waste Management

The discussion has established that MSW emanates as a by-product of social activities. Therefore, this study‘s theoretical foundation involves exploring social, economic, and solid waste management principles that serve as a lens through which the study‘s ideas are examined. The following sections highlight the foundations of some of these principles as a framework for the research.

2.14.1. The Sustainable Development Goals (SDGs)

The United Nations (UN) Sustainable Development Goals (SDGs), which came into effect on 1 January 2016, is a landmark agreement by all countries on a blueprint for a better future. The SDGs is a collection of 17 global goals that cover major global issues, including climate change, poverty alleviation, energy, poverty, hunger, education, public health, gender equality, water sanitation, social justice, urbanisation and environment and the guided efforts in tackling these issues by 2030 (Bhatta, 2018). Amongst the 17 global goals is the drive to encourage sustainable consumption and production patterns and sustainably reduce waste generation through prevention, reduction, recycling and reuse, as emphasised in Goal 12.

Although Goal 12 specifically addresses MSWM-related issues, Rodic and Wilson (2017) pointed out that MSWM can be easily linked to 12 out of the 17 United Nations sustainable development goals; this notwithstanding, the socioeconomic development of most developing countries continues to suffer from the threat of poor sanitary practices; with Rodic and Wilson (2017) concluding that the issue of poor sanitary practices will continue to persist especially in developing countries until effective legislation is in place and enforced, as well as substantial financing and overall behavioural change. Mainly from the legislative and behavioural change perspectives, adopting sustainable models such as the waste hierarchy, ISWM, and CE presents the likely way to deal with the MSWM issues.

Table 0.4 *Key SDGs Relating to Waste Management*

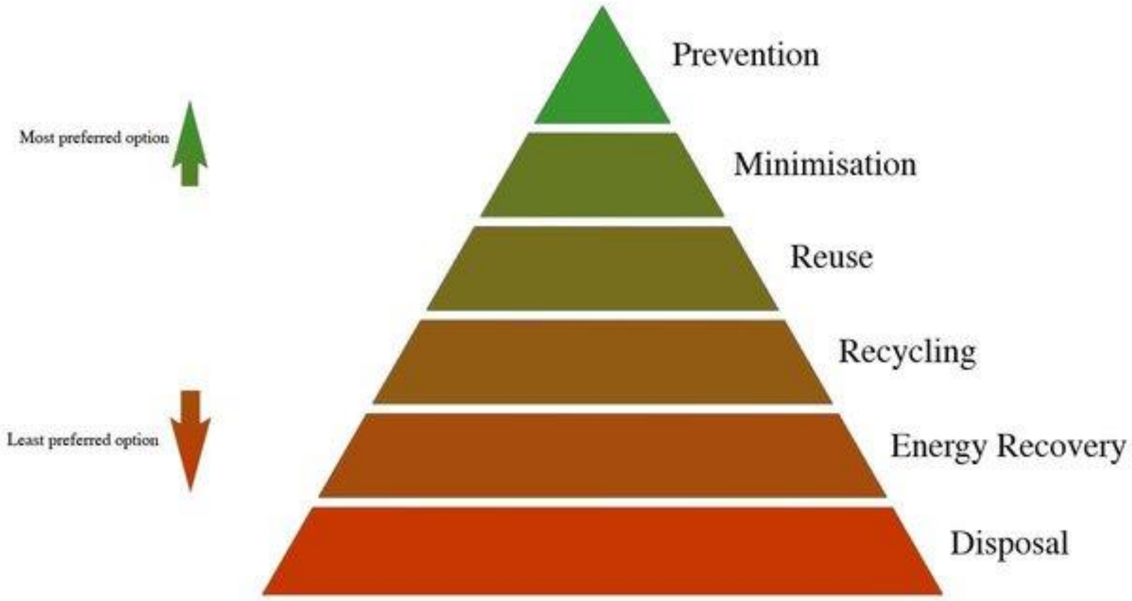
SDG GOALS	TARGETS	RELATION TO MSW
Goal 2. Zero Hunger	End hunger, achieve food security and improved nutrition and promote sustainable agriculture.	Yes, relating to target 2.4.
Goal 3. Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages	Yes, relating to targets 3.3, 3.4, 3.9, 3.d
Goal 6. Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all.	Yes, and relating to all targets
Goal 7. Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.	Yes, especially for Target 7, which promotes renewable energy technology
Goal 8. Decent Work and Economic Growth	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.	Yes, and relating to Target 8.4.
Goal 9. Industry, Innovation, and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation.	Yes, relating to Target 9.4.
Goal 11. Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable.	Yes, relating to Target 11.6, 11.7, 11.a & 11.b.
Goal 12. Responsible Consumption and Production	Ensure sustainable consumption and production patterns	Yes, all targets
Goal 13. Climate Action	Target urgent action to combat climate change and its impacts	Yes, all targets
Goal 14. Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development.	Yes, relating to Targets 14.1 – 14.3
Goal 15. Life on Land	Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	Yes, relating to 15.1, 15.3, 15.8
Goal 16. Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable, and inclusive institutions at all levels.	Yes, target 16.7 relating to decision-making in developing sustainable plans

Note: Adopted from Rodic & Wilson, 2017

2.14.2. Waste Hierarchy Model

Most developed countries have embraced the Waste Management Hierarchy as an MSWM approach (Yakubu & Zhou, 2019). Since the 1980s, the waste hierarchy has determined suitable waste management solutions. It is focused on assumed environmental impacts (Hultman & Corvellec, 2012). To protect public health and ensure environmental protection, the waste hierarchy was developed to prioritise waste avoidance, recycling, and reuse over waste management and disposal (DEFRA 2011; Hultman & Corvellec, 2012; van Ewijk & Stegemann, 2016). The waste hierarchy lists waste management practices in the order of environmental impact from the highest to the lowest: waste reduction, reuse, recycling and composting, energy recovery, and landfilling (Williams, 2005). The waste hierarchy (Figure 2.7) prioritises preventing waste in the first place. When waste is created, it prioritises preparing it for reuse, recycling, recovery, and last of all disposal in landfill (DEFRA, 2011).

Figure 0.9 *The Waste Hierarchy*



(*Note*: from Hong *et al*., 2016)

Furthermore, the Waste Framework Directive's 5-stage waste hierarchy addresses more than waste management issues, as waste prevention is widely regarded as falling outside the waste management spectrum. Waste prevention entails prolonged product usage and effective management of scarce resources to avoid unnecessary waste generation (van Ewijk & Stegemann, 2016; Sakai *et al.,* 2017). The most preferred approach to MSWM is not to create waste in the first place; this could be in the form of discouraging the purchase of unsuitable groceries, which leads to buying or preparing too much food. Preparation for reuse includes reusable packaging systems that can eliminate the need for disposable packaging and better product protection, thus reducing product damage and losses associated with it.

Recycling entails collecting, sorting, and processing wastes into raw materials used as input in producing new products. In this view, the recycling stage discourages using new materials that will produce additional waste, resulting in less pollution and better energy efficiency (Van Ewijk & Stegemann, 2016). The fourth priority in the waste hierarchy emphasises energy recovery through incineration or anaerobic digestion of MSW that otherwise cannot be recycled (Lombardi *et al*., 2015). Disposal is the final treatment of MSW according to the waste hierarchy. The waste hierarchy recognises that specific waste cannot be recycled safely, and disposal or treatment is the most appropriate MSWM option. Landfills remain the oldest and most common practice for MSW disposal and continue to be practised in most developing countries (Andriani & Atmaja, 2019; Yong *et al*., 2019).

In the United States, landfill practices persist under stringent regulations that adhere to the standards set forth by the Environmental Protection Agency (EPA). These landfills are subject to oversight and management at various levels, including tribal, local, and state jurisdictions (Omar *et al*., 2016). This regulatory framework ensures that landfill operations are controlled, minimising environmental impacts and adhering to established waste disposal and containment guidelines. In the EU, many member countries mainly discourage landfills as a means of MSW disposal (Hoornweg & Bhada-Tata, 2012). Among the EU countries, MSWM statistics indicate that Belgium and Italy are more inclined to recycle, whereas Sweden, Greece, and Bulgaria still favour landfilling (Eurostat, 2017). The Landfill Directive (1999/31/EC) is one legislative in the EU that minimises landfilling among EU member countries to reduce landfills' adverse effects on the environment and human health (Fischer *et al.,* 2017). Nonetheless, landfills are still a vital disposal process as they offer a significant source of methane gas, a by-product of decaying organic matter. The methane gas can be recovered as an energy source (Yong *et al.,* 2019).

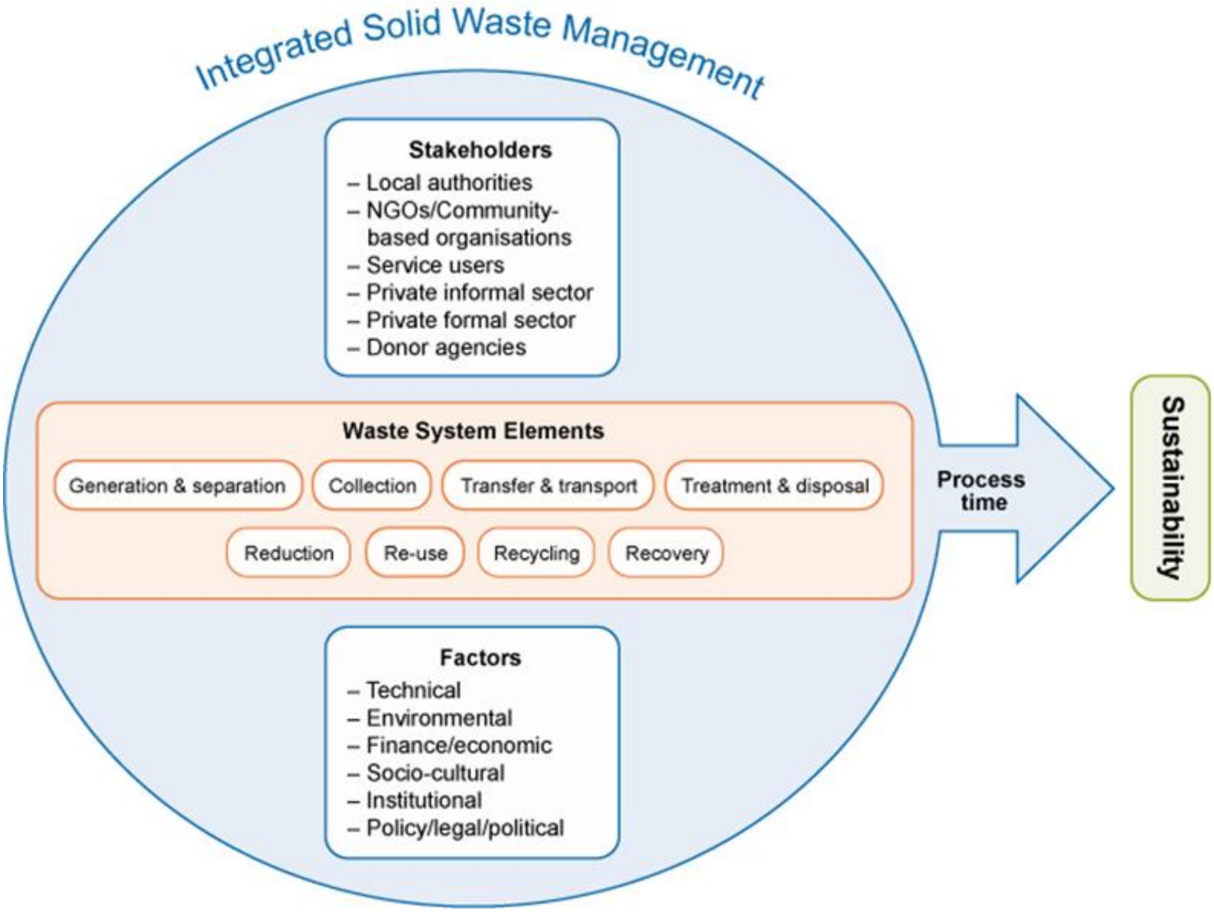
These arguments imply that waste disposal represents a significant principle of sustainable MSWM. According to Van Ewijk & Stegemann (2016), the waste hierarchy promotes sustainability by dematerialising the MSW by dissuading landfills and discouraging waste accumulation through waste recovery, recycling and reusing, thereby averting environmental degradation. More recently, the hierarchy has been critiqued for its lack of scientific basis, difficulty in implementation, and failure to account for specific local situations, which should dictate which technologies are appropriate and preferable. Integrated waste management has emerged as a vastly different approach (Hoornweg & Bhada-Tata, 2012).

According to Gertsakis and Lewis (2003), the hierarchy is difficult to implement because industry experts and the government have little control over production decisions that could influence higher-level priorities, such as waste prevention and minimisation. As Bartl (2014) suggested, one significant barrier to effective hierarchy implementation is the need for all major stakeholders to make appropriate decisions on MSWM technologies and production decisions that influence MSW generation. Hence, any consideration of waste hierarchy needs to consider each MSWM option and any avoided impacts throughout the life cycle, that is, from substituting recycled materials for virgin material (Bartl, 2014; Van Ewijk & Stegemann, 2016).

2.14.3. Integrated Solid Waste Management (ISWM)

Integrated Solid Waste Management (ISWM) represents a modern-day and systematic approach to MSWM. ISWM is a complete management system for reducing, collecting, compositing, recycling, and disposing waste (EPA, 2016). Shekdar (2009) described ISWM as a holistic approach to handling MSW in an economically and environmentally sustainable manner that is also socially acceptable. Hence, ISWM considers MSWM a means for protecting against environmental degradation and improving public health within each local context and requirement (Pharino, 2017; Cobo *et al*., 2018). Unlike the waste hierarchy that focuses on a methodological or procedural approach, the ISWM system offers a more flexible system that combines a variety of MSW treatment options comprising of MSW collection, treatment, reduction, reuse, recycling, composting and disposal techniques into a practical MSWM solution that is environmentally and socio-economically sustainable (Cobo *et al.,* 2018). Figure 2.8 details the elements of a typical ISWM system. The ISWM approach recognises that MSW can be a complex mixture of diverse waste materials requiring a matching mix of treatment options.

Figure 0.10 *Integrated Solid Waste Management Model*



(*Note*: From OU, 2016)

It also recognises that, within the local context, infrastructure, financial, and technical resources are available to implement and support the adopted treatment technologies. The ISWM systems look beyond the 3Rs (Reuse, Recycling and Recovery) to incorporate stakeholders' participation and consider the waste elements and influencing factors in the local context (Yukalang *et al*., 2018). In other words, ISWM looks beyond the available waste management options or whether such options have been proven to be successful in a different context to look for the best mix of waste management options that minimise economic costs and maximises environmental protection and social benefits (Cobo *et al.*, 2018). The combination level within any ISWM system will depend upon the prevailing local conditions. For example, a waste management system in one city incorporating recycling, incineration with energy recovery, and landfill may provide a different result from another city's solution, which incorporates recycling, composting, and landfilling.

ISWM, based on local needs and conditions, can become an effective policy tool for developing countries, regardless of existing waste management practices or level of economic development (Marshall & Farahbaksh, 2013). Also, with careful planning, ISWM can help mitigate the influence of external stressors (such as economic and population growth) on waste management and contribute numerous benefits, including (i) human health (improve quality of air and water and reduce the spread of disease), (ii) climate change and the environment (mitigation of emissions of short-lived climate pollutants that have a warming influence on climate), (iii) the economy (means to job creation and encourage the development of new markets) and (iv) social benefits (reducing foul odours and improving the quality of life for informal recycling sector – i.e., pickers). Nonetheless, addressing the issue of environmental degradation and dealing with the shrinking global resources is still a big challenge for the linear approaches to MSWM (Michelini et al., 2017; Hysa et al., 2020).

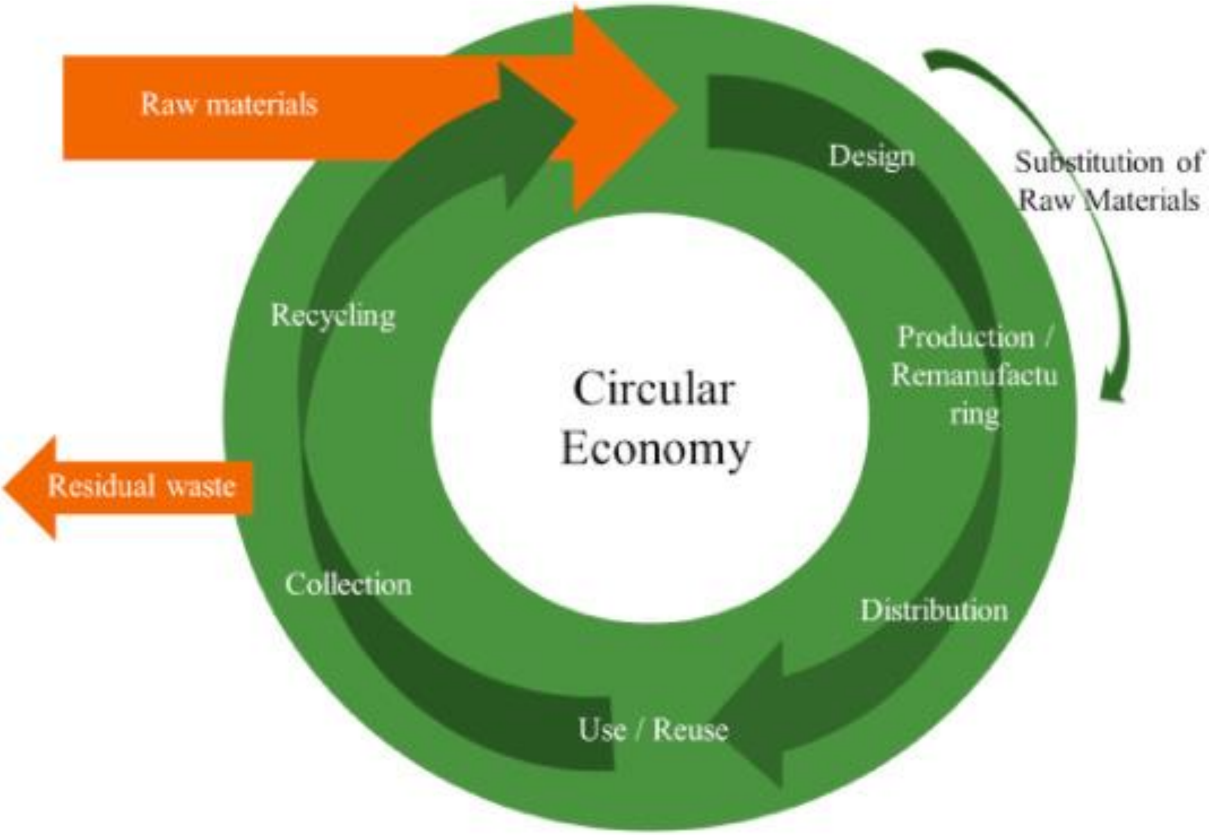
2.14.4. The Circular Economy (CE)

The CE is a widespread concept endorsed by the EU (Kirchherr *et al.,* 2018) and is promoted by other national governments and businesses worldwide. It encompasses an economic framework that emphasises sustainability in creating products and services; this is achieved by reducing the utilisation and wastage of resources such as raw materials, energy, and water, alongside minimising waste production (Sehnem *et al*., 2019). The industrial economist drives this perception of the CE, who sees this as a means of actualising sustainable development where waste material and residual energy flows are recycled in the production chains (Lazarevic & Valve, 2017; Bocken *et al*., 2014; Webster, 2015). Lieder and Rashid (2016, p.37) describe a CE "as a solution for harmonising ambitions for economic growth and environmental protection". Ghisellini et al. (2016) make a bolder claim by describing the CE as a formidable framework that stimulates modern businesses to adopt a more radical preventive and regenerative development process that recovers environmental resources.

Geissdoerfer *et al*. (2017), conducting a systematic review on CE, concluded that it is a means of achieving sustainability, a beneficial relation, or a trade-off. The CE is described by Nikolau *et al*. (2021) as a regenerative system that aims to minimise resource input, waste, emissions, and energy leakages by actively managing material and energy flows. This concept involves strategies such as slowing down resource consumption, closing material loops through recycling and reusing, and narrowing energy loops to reduce environmental impacts. Proponents of the CE view the Earth as a self-contained spherical system, emphasising the importance of achieving sustainability through a harmonious integration of economic progress, social inclusivity, and environmental adaptability. This holistic approach seeks to benefit current and future generations (Geissdoerfer *et al.,* 2017; Sopjani *et al*., 2020). Thus, from the CE perspective, MSW is regarded as a resource that must be recovered and reclaimed through recycling and reuse, with the value of the extract and produces kept in circulation through deliberate and unified dynamic chains (Michelini *et al.,* 2017; Sehnem *et al.,* 2019). Thus, the focus of MSWM is diverted from waste as a by-product of the production process but as a resource for production (Gregson *et al.,* 2015).

The significant difference between the CE approach and ISWM is that while the latter promotes preventive measures, the former promotes restorative measures. Under the CE approach, valueless MSW streams are considered resources for a new tier of the economy as they are recovered (or prevented from being lost) through greater efficiency and management at every stage of production and consumption. Some hazardous or toxic materials may be recycled or refined for reuse (Ellen MacArthur Foundation, 2013). In other words, all outputs become input to other production processes or are returned to natural systems as benign emissions rather than pollutants. Figure 2.9 illustrates the phases of the CE, with each phase emphasising the need to reduce cost and overdependency on natural resources in the manufacturing process. The main objective of the CE is to maximise the use of MSW streams through collection, reuse, and recycling (Akanbi *et al.,* 2018).

Figure 0.11 *The Circular Economy Model*



(*Note*: From Grafström & Aasma, 2016)

2.14.5. Theoretical Synthesis

The primary aim of this study is to explore the potential of WtE technologies as a sustainable waste management solution in Nigeria. The discussion has shown that the global waste management landscape is facing escalating challenges with significant environmental, social, and economic consequences. Hence, adequate waste management is imperative for sustainable development and aligns with the CE principles, which emphasise minimising waste generation and maximising resource efficiency. Current trends project a considerable surge in waste generation, particularly in developing countries, including Nigeria. Despite the country's commitment to the UN SDGs, effective MSWM remains a critical issue, leading to environmental degradation. This literature review indicates that Nigeria's waste management system grapples with inefficiencies such as inadequate waste collection, lack of recycling and segregation practices, and open dumping. This situation calls for immediate attention, especially considering the country's growing concern about the depletion of natural resources and the imperative of mitigating climate change.

The CE framework provides a robust foundation for addressing these challenges. The CE aligns with sustainability principles by viewing waste as a valuable resource and integrating it into the production cycle. In this context, WtE technologies present a viable option for managing non-recyclable waste. These technologies convert waste into clean energy forms, significantly reducing landfill volumes while generating renewable energy. However, the successful implementation of WtE technologies necessitates a comprehensive approach. An ISWM system involving waste prevention, collection, treatment, recycling, and energy recovery is crucial. Effective waste stream management requires stakeholder engagement, robust infrastructure, and well-defined policy frameworks. Moreover, the CE principles, which advocate for product design that facilitates recycling and reuse, further support waste reduction and responsible consumption practices.

Integrating WtE technologies in waste management strategies aligns with the SDGs and addresses multiple objectives. It minimises environmental impacts, conserves resources, and curtails greenhouse gas emissions. By implementing waste reduction, recycling, and WtE measures, Nigeria and other developing countries can make significant progress towards achieving SDG 12 (Responsible Consumption and Production) and SDG 7 (Affordable and Clean Energy). Overall, the adoption of these principles necessitates a collaborative effort. It calls for Governments to establish supportive policies that incentivise WtE solutions alongside other waste management methods. These policies can drive businesses to contribute by adopting circular business models, investing in eco-design, and promoting recycling initiatives. Furthermore, communities and individuals will play a crucial role in waste separation, recycling, and adopting sustainable consumption behaviours.

2.15. Different Approaches to waste reduction and management and Position of Waste to Energy (WtE) as an option

There are several critical approaches to waste reduction and management, with Waste-to-Energy (WtE) being one crucial component of an integrated waste management strategy (Saghir & Santoro, 2018). The waste hierarchy prioritises different waste management options based on their environmental impact. The most preferred options are:

1. **Waste Reduction**: Minimizing waste generation by reducing packaging, promoting product durability, and encouraging a shift towards a circular economy.
2. **Reuse**: Finding alternative uses for waste materials, such as donating used goods or repurposing items.
3. **Recycling**: Recovering and reprocessing waste materials into new products.
4. **Recovery**: Extracting value from waste through methods like composting or energy recovery.

2.15.1. Waste-to-Energy (WtE)

WtE is a form of energy recovery that involves converting waste materials into electricity, heat, or fuel. It can help reduce the volume of waste sent to landfills while providing a renewable energy source. WtE technologies include incineration, anaerobic digestion, and pyrolysis (Debrah et al., 2022). These processes can generate energy while reducing waste disposal's environmental impact. Other approaches include:

- **Improved waste collection and segregation**: Ensuring efficient waste collection and separating materials at the source facilitates recycling and recovery.
- **Sanitary landfilling**: Properly engineered landfills with leachate management and methane capture can minimise the environmental risks of waste disposal.
- **Public education and policy**: Government policies and regulations can drive behavioural changes by raising awareness about waste reduction and providing incentives for sustainable practices.

Combining these approaches is needed to manage waste effectively, focusing on reducing waste generation and maximising resource recovery. WtE can play a role in this integrated waste management system. However, it should be considered in the context of the overall waste hierarchy and other waste reduction and diversion strategies (Debrah *et al.,* 2022).

2.15.2. Environmental Impact of Waste-to-Energy

Reduction of Landfill Use: WtE significantly reduces the volume of waste sent to landfills. It can decrease waste by up to 87%, converting 2,000 pounds of garbage into just 300 to 600 pounds of ash. This reduction is crucial as landfills contribute to greenhouse gas emissions, mainly methane, which is about 25 times more potent than carbon dioxide over 100 years (Saghir & Santoro, 2018).

Greenhouse Gas Emissions: While WtE produces carbon dioxide, it does not generate methane, making it a preferable option to landfilling. The emissions from WtE are generally lower than those from landfills, as the latter release both carbon dioxide and methane during waste decomposition. However, WtE plants still emit CO_2 and other pollutants, raising concerns about air quality and health risks for nearby communities.

Energy Production: WtE facilities generate renewable energy, which can help reduce reliance on fossil fuels. This energy can power homes and industries, creating a more sustainable energy mix. By harnessing energy from waste, WtE supports a circular economy, where waste is viewed as a resource rather than merely a disposal issue (Sinthumule & Mkumbuzi, 2019).

2.15.3. Comparison with Other Waste Management Strategies

Recycling: Recycling is generally considered more environmentally friendly than WtE because it conserves resources and reduces the need for new raw materials. However, not all waste can be recycled, and WtE can process materials that are otherwise non-recyclable. The challenge lies in ensuring that WtE does not disincentivise recycling efforts by providing a more accessible alternative for waste disposal.

Composting: Composting is another eco-friendly waste management strategy focusing on organic waste. It enriches the soil and reduces the need for chemical fertilisers. Unlike WtE, composting does not produce energy but contributes to soil health and reduces landfill volumes. WtE can complement composting by handling non-compostable materials, but there is a risk that it may divert focus from composting initiatives (Saghir & Santoro, 2018).

Landfilling: Landfills are the least desirable option in the waste hierarchy due to their significant environmental impacts, including land use, methane emissions, and potential groundwater contamination. WtE serves as a better alternative by reducing the volume of waste and minimising the environmental footprint associated with landfilling. While Waste-to-Energy presents several advantages, including reduced landfill use and energy production, it is not without its drawbacks, such as emissions and potential health risks. It is most effective when integrated into a broader waste management strategy prioritising waste reduction, recycling, and composting. The environmental impact of WtE must be carefully weighed against other strategies to ensure that it contributes positively to sustainability goals rather than undermining them (Ezendu & Aguwamba, 2021; Ogweleka, 2013). Countries exhibit varying preferences for WtE technologies based on several factors, including economic conditions, energy needs, waste management challenges, and environmental policies.

2.15.3.1. Economic and Energy Needs

1. **Energy Generation**: Countries facing energy shortages or heavily reliant on fossil fuels often turn to WtE to diversify their energy sources. For instance, the United Arab Emirates is developing WtE facilities to contribute to its Renewable Energy Strategy 2050, which aims to increase clean energy contributions significantly.
2. **Cost-Effectiveness**: WtE can be seen as a cost-effective solution for managing waste while generating energy in developing nations. This dual benefit particularly appeals to regions lacking waste management infrastructure and high energy demand.

2.15.3.2. Waste Management Challenges

1. **Growing Waste Volumes**: Countries experiencing rapid urbanisation and population growth face increasing waste generation. WtE provides a viable

option to manage this waste sustainably, especially in areas where landfill space is limited or where landfill management poses significant environmental risks (Ogweleka, 2013).

2. **Landfill Alternatives**: Due to environmental concerns, traditional waste disposal methods, such as landfilling, are becoming less acceptable in many regions. WtE offers an alternative that reduces landfill use while addressing waste disposal challenges.

2.15.3.3. Environmental Policies and Regulations

1. **Supportive Legislation**: Countries with strong environmental policies and regulations may promote WtE as part of a broader strategy to reduce greenhouse gas emissions and improve waste management practices. For example, the European Union has implemented various directives encouraging waste recovery and recycling, which can include WtE as a comprehensive waste management approach component.

2. **Public Acceptance and Awareness**: The public acceptance and understanding of WtE technologies can influence their adoption. In some countries, community support for WtE initiatives is driven by increased awareness of the environmental impacts of landfilling and the benefits of energy recovery from waste (Ganda, 2020; Hoinaru *et al*., 2020).

2.15.3.4. Technological Capability

1. **Infrastructure Development**: Countries with the technological capability to implement and manage WtE facilities are more likely to adopt these systems; this includes having the necessary engineering expertise and financial resources to build and operate WtE plants effectively (Ahmed *et al*., 2022).

2. **Innovative Practices**: Some nations are exploring advanced WtE technologies, such as anaerobic digestion and gasification, which are perceived as more environmentally friendly than traditional incineration methods; this innovation can drive preferences for WtE in countries looking to sustainably enhance their waste management strategies.

2.16. Energy Recovery from Municipal Solid Waste

Energy recovery from MSW, or WtE, has emerged as a promising and eco-friendly approach for generating electricity and heat, offering an environmentally viable solution that aligns with legal and societal demands (Khoshand *et al*., 2018; Thomas & Soren, 2020). The technologies address the challenge of MSW management and contribute to reducing landfill space requirements and mitigating greenhouse gas emissions (Yusoff & Zakaria, 2012; Ham & Lee, 2017). The increasing global demand for WtE technologies is evident from the recent expansion of the market. By the year 2022, there were approximately 2,600 operational WtE facilities across the globe. These facilities collectively could effectively handle and process around 460 million tons of waste annually (Ecoprog, 2023). More than 504 of these WtE plants are in operation in Europe, and over 54 WtE plants are in the UK (CEWEP, 2020).

Mutz *et al*. (2017) posit that the growing global interest in WtE solutions is driven by the increasing concern to address the depletion of natural resources and mitigate the adverse environmental and climate change impacts caused by inadequate MSWM practices. However, developing countries tend to be more attracted to the energy potential. Hence, in sustainable development, Table 2.5 shows that WtE options present a range of positive and negative impacts (Khan *et al*., 2022). However, these impacts must be carefully assessed to determine the overall contribution of WtE technologies to sustainable development goals.

Table 0.5 *Impacts of WtE in Relation to Sustainability*

Sustainability Dimensions	Positive Impacts	Negative Impacts	Dominant Impact Type
Social	Improvement to public health Odour reduction Waste Reduction Local renewable energy generation Improved life within the local community	Increased noise and dust due to waste vehicles	Positive
Economic	Revenue generation Job creation Avoidance of disposal cost	Local land value might be increased	Positive
Environmental	Reduced air pollution Reduced odour pollution Less use of fossil fuels Renewable energy generation By-products for composting	Emissions from WtE plants	Positive

(*Note*: Adapted from Khan *et al*., 2022)

The potential for the biodegradable MSW-driven WtE arises from the vast volume of MSW generated globally, estimated to grow from 1.3 billion tonnes in 2012 to about 2.2 billion tonnes in 2025 (Hoornweg & Bhada-Tata, 2012). Though there is huge potential for WtE deployment in energy generation, the challenge with implementing such technologies is that each country is unique, considering the factors that drive such technologies differ (Nixon *et al.,* 2017; Thomas & Soren, 2020). For example, country-specific factors such as uncertainty in government policy, economic inadequacies and varying composition of MSW because of varying human activities and consumption patterns have been cited to affect the implementation of WtE technologies (Khan *et al*., 2021).

The significance of comprehending and applying WtE technologies in Nigeria is immense, particularly in light of the deficiencies identified in Nigeria‘s approach to MSWM. The predominance of organic materials identified in the literature introduces a critical consideration. Adopting a technology solely based on its success in other countries, particularly industrialised and developed ones, may be hasty (Kaza *et al*., 2018). These unique challenges, therefore, require a careful investigation of the current WtE technologies and deep insight into the feasibility of deployment within the Nigerian context. Regardless, embracing WtE technology may be crucial for mitigating current challenges to socio-economic growth in Nigeria, including inadequate landfilling, poor electricity supply, and reducing Nigeria’s carbon footprint.

2.16.1. An Overview of WtE Technologies

In recent years, technological innovations have significantly advanced the development of WtE systems. Although various new technologies have been developed, some mature or tested technologies remain dominant in the WtE market. Figure 2.10 highlights some standard WtE technologies under the different conversion categories.

Figure 0.12 ***Waste to Energy Conversion Categories***

(*Note*: From Kumar & Sammader, 2017)

2.16.2. Thermal Conversion Technologies

Energy conversion from MSW through thermal conversion is one of the oldest forms of energy recovery from waste practised in developed and developing countries (Sarah & Misran, 2018; Ghenai *et al*., 2020). Thermal conversion is a technique that is used to transform MSW into fuels, by-products, and power (Lu *et al.,* 2012). The thermal conversion technique is most suitable when MSW cannot be subjected to thermochemical or biological treatments (Kumari *et al*., 2019). This process is often used for MSW reduction, energy production and recovery, and diversion of wastes from landfills, representing a potentially important component of MSWM systems (Kumari *et al*., 2019). Within the thermal conversion system, the organic constituents of the MSW are gaseous products, carbon dioxide and water, which do not have fuel value but are carriers of the heat of combustions as in biomass boiler-furnace systems (Green & Zimmerman, 2012).

Unlike other conversion processes, such as the chemical and biological systems, the thermal conversion process requires the MSW to be set at a pre-conditioned state in terms of composition and characteristics before subjecting to a heat treatment at a very high temperature to the MSW feedstock (Lu *et al.,* 2012; Kumari *et al.*, 2019). However, recent thermal conversion technologies can now treat MSW with some moisture content. According to Zhao *et al*. (2016), China faces similar waste composition challenges, with a significant amount of food waste characterised by low calorific value and high moisture content, a common feature in other developing nations. China has pioneered the development of innovative circulating fluidised bed-based incineration plants to tackle this situation. Presently, 28 of these plants are in operation, collectively processing 800 tonnes of municipal solid waste (MSW) daily. Notably, these plants have successfully generated electricity from the waste, showcasing a potential solution to the energy and waste management concerns prevalent in many developing countries (World Energy Resources, 2016).

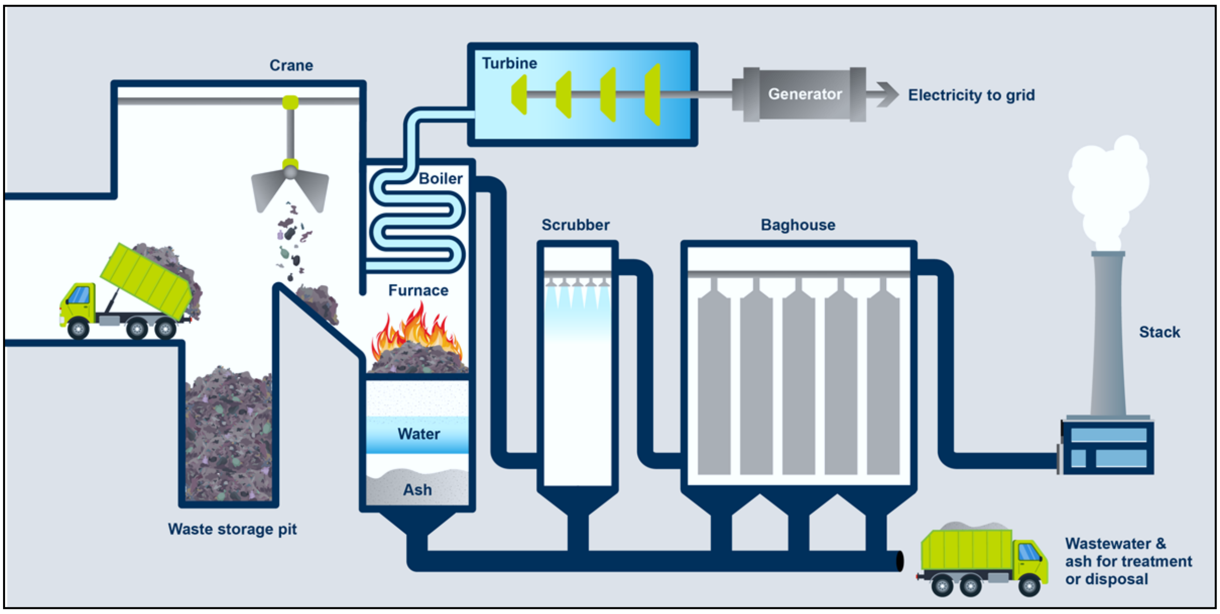
The fundamental principle of the thermal conversion process is the understanding that only fuel gases burn and release heat, that liquids and solids do not burn themselves but consume heat in the drying and volatilisation process required for them to be chemically converted into fuel gases (Badwal & Giddey, 2010). The primary fuel intermediates are the volatile hydrocarbons and energy-rich organic molecules, carbon monoxide (CO) and hydrogen (H_2). Two standard thermal conversion processes of interest to this study are direct combustion and incineration.

2.16.2.1. Incineration

Incineration conversion alongside direction combustion is a widely accepted technology for treating MSW with or without the option of energy recovery (Guerrero *et al.,* 2013). Incineration is a thermal conversion process that subjects the MSW feedstock to the combustion process in the furnace in excess air to foster mixing and turbulence, ensuring a safe and complete burning of MSW materials (Thomas & Soren, 2020). The incinerator's flame zone is designed to sufficiently break down all organic and many inorganic molecules, allowing reactions between the waste's most volatile components and the air's oxygen and nitrogen. The predominant reactions are between carbon and oxygen-producing carbon dioxide (CO_2) and between hydrogen and oxygen, producing water vapour (H_2O). Incomplete combustion of the organic compounds in the MSW feedstock produces some carbon monoxide (CO) and carbon-containing particles.

Hydrogen reacts with organically bound chlorine to produce hydrogen chloride (HCl). Also, many other reactions occur, producing sulphur oxides (SOx) from sulphur compounds, nitrogen oxides (NOx) from nitrogen compounds (and a little from the nitrogen in the air), metal oxides from compounds of some metals and metal vapours from compounds of others. The by-product of the combustion process is the formation of ashes, which are disposed of in landfills, and solid slags, which are valorised. The metals are recycled into the recycling industry, and the slags are used in civil construction, such as wood flooring and landfill covering (Green & Zimmerman, 2012). Incineration plants, unlike direct combustion technologies, can reduce the volume of MSW by 80-90% (Singh *et al.*, 2011; Thomas & Soren, 2020), with some modern incineration plants reported to reduce the MSW volume by 95% without compromising electricity and heat generation (Thomas & Soren, 2020). Green and Zimmerman (2012) state that the largest incinerators can treat 1000-3000 tonnes of MSW daily.

Figure 0.13 *MSW Incineration Process*



(*Note*: From CQU, 2021)

Although all incinerators follow the same principle, incineration technologies are categorised as mass burns, refuse-derived fuel and fluidised bed incineration (Gupta *et al.,* 2015; Nixon *et al*., 2017). The MSW is burned as delivered in the mass-burn incineration, with only metal components removed from the MSW stream. Air ducts below and above the fire zone provide combustion air for the mass-burn system. Control of the combustion is achieved by sectioning the under-fire primary air system. In contrast, the complete combustion of the gas stream is determined by air jets, the furnace and boiler sizes, timing, turbulence, and temperature. The main advantage of mass burn is that it is a well-established technology that is reliable over time, requires minimal processing of the MSW stream, and provides good thermal efficiency. The disadvantage is that it is very capital-intensive and takes time to design and build.

The fluidised bed incineration technologies are relatively small combustion systems, typically ranging from a capacity of 5 to 100 tonnes per day (Leckner & Lind, 2020). To increase capacity, multiple units must be installed. The MSW feedstock is converted to a liquid state by passing liquid or gas through it, creating drag forces that cause the material to separate. For fluidised bed sewage sludge incineration systems, preheated air is employed in fluidising a bed of sand, which mixes violently to break up the MSW feedstock as it is delivered while at the same time allowing for combustion by distributing oxygen over an extensive surface area (Anderson *et al.,* 1996; Donatello & Cheeseman, 2013). This type of incineration can limit the emission of air pollutants by burning at a relatively low temperature, which minimises the vaporisation of the MSW feedstock's metallic components and slagging of glass components delivered to the secondary chamber to allow for complete combustion.

Aside from low air pollutant emission, fluidised bed incineration has other advantages such as fast design and construction time, low cost of building and high flexibility. Low capacity, lower thermal efficiency, shorter lifespan of technology and higher cost of maintenance are small of its drawbacks. Lastly, refuse-derived fuel (RDF) incineration technology offers the option of generating steam, electricity, and heat from MSW (Vounatsos *et al*., 2015). RDFs differ from mass burns and fluidised beds as they are designed to separate MSW into combustible and non-combustible fractions. The non-combustible fractions of the MSW, such as glass, plastics and metals, are recycled or landfilled. Some advantages of RDFs include low moisture content, higher calorific value, homogeneous fuel stock, large storage capacity arising from the compact size, and ease of transformation (Johari *et al*., 2014). Some disadvantages include the need for refining and pre-processing facilities to avoid slagging in the bed combustors and the high design cost (Johari *et al*., 2014). Figure 9 shows a life cycle diagram of a typical incineration plant with energy recovery.

Overall, thermal WtE facilities often have high initial development costs, although once operational, they tend to maintain stability over an extended period (Kaza & Bhada-Tata, 2018). Furthermore, thermal conversion processes are widely criticised for environmental pollution. This drawback positions them as less preferable options for energy recovery, considering the emphasis on environmental protection measures. As a result, these technologies are not always aligned to minimise environmental impact and promote sustainable waste management practices.

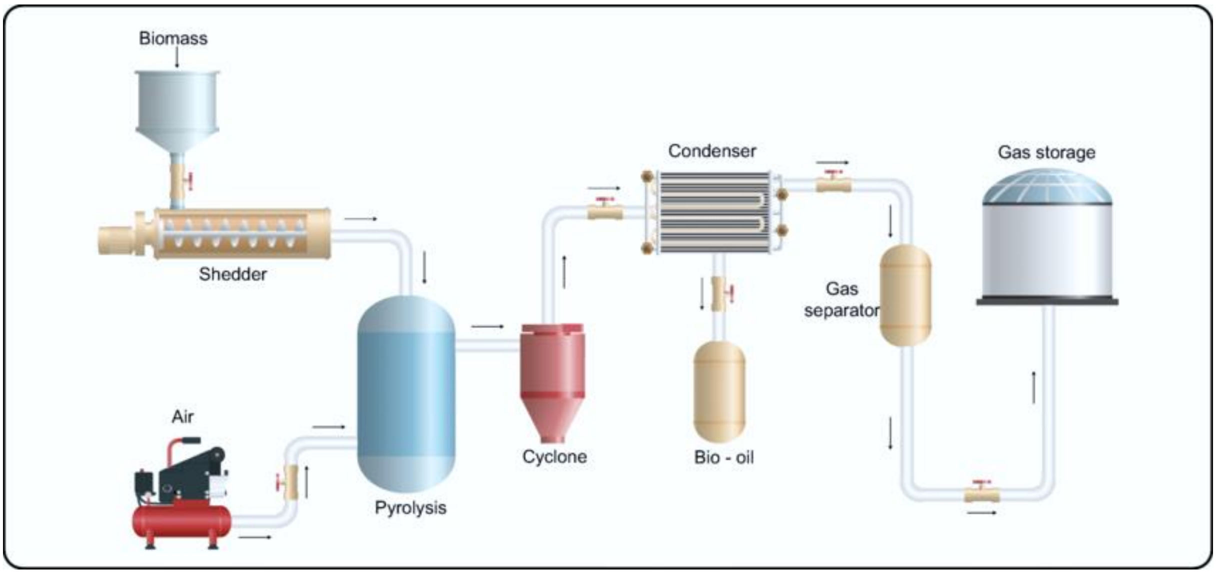
2.16.3. Thermochemical Conversion Technologies

Thermochemical conversion (also referred to as advanced thermal conversion) refers to the controlled heating and oxidation of MSW to produce intermediate energy carriers (such as producer gas, oils, or methanol) or heat. The thermochemical conversion technologies are classified by their associated oxidation environment, particle size and heating rate, ranging from heating MSW in an oxygen-free environment to complete exothermic oxidation of MSW (Tanger et al., 2013). Thermochemical conversion technologies offer distinct advantages over thermal processes, primarily due to their greater cost-effectiveness and ease of implementation (Sarah & Misran, 2018). Additionally, these technologies afford greater flexibility in utilising MSW feedstock and are more energy efficient (Stapf *et al*., 2020). Within thermochemical conversion, two prevalent methods are pyrolysis and gasification.

2.16.3.1. Pyrolysis

Pyrolysis is the thermal decomposition of MSW without oxygen into highly heterogeneous solid, liquid, and gaseous intermediates (Tanger *et al.,* 2013; Kundu *et al*., 2017). The solid by-product can be used as fuel or soil amendment. At the same time, the liquid product is a heterogeneous mixture characterised by high oxygen content and alkalinity, which can be upgraded to fuels or chemicals. Gaseous products include hydrogen, methane, and carbon monoxide. Given the lack of oxygen, the MSW materials do not combust but undergo thermal decomposition of the chemical compounds (i.e., cellulose, hemicellulose, and lignin) into combustible gases and charcoal (Miandad *et al*., 2019). The pyrolysis process of MSW is very complex and consists of both simultaneous and successive reactions when MSW is heated in a non-reactive atmosphere. Thermal decomposition of the organic components of the MSW begins at 350^0C – 550^0C and rises to 700^0C – 800^0C in the absence of oxygen (Stapf *et al.,* 2020).

Figure 0.14 *Diagram of Pyrolysis Process*



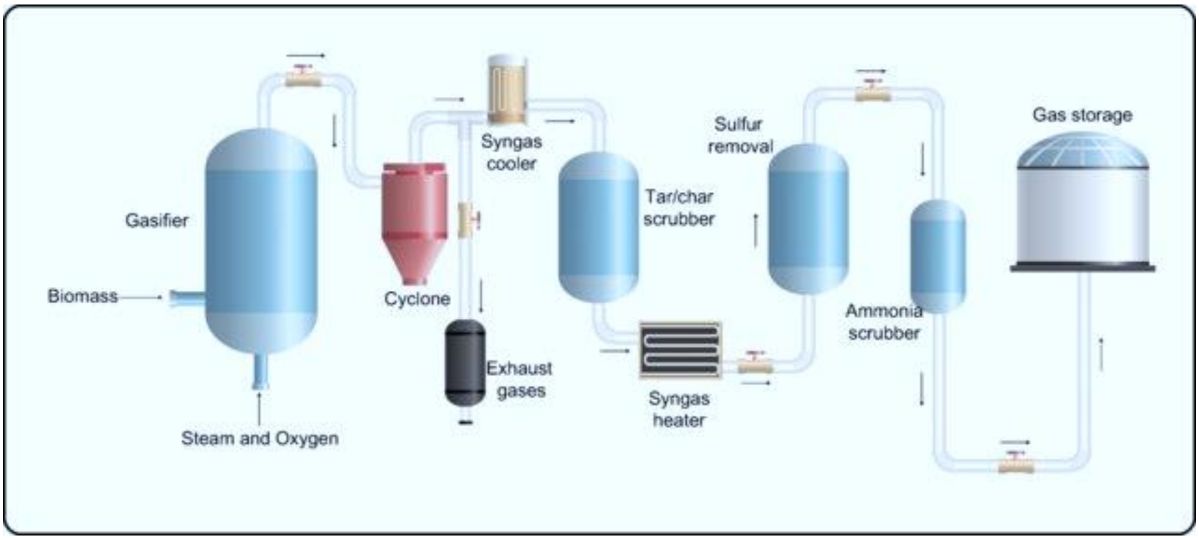
(*Note*: from Kumar *et al*., 2020)

The long chains of carbon, hydrogen and oxygen compounds in biomass break down into smaller molecules in the form of gases, condensable vapours (tars and oil) and solid charcoal. The extent and rate of decomposition of MSW components depend on the process parameters of the reactor temperature, heating rate, pressure, reactor configuration and the composition of the MSW (Jahirul *et al*., 2012). One significant benefit of the pyrolysis process is that it can self-sustain its processes, as the combustion of the syngas and a portion of the pyrolysis oil or biochar can be used to drive the entire processes (Green & Zimmerman, 2012; Stapf *et al.,* 2020). Further, the pyrolysis oil can be harnessed as an alternative to petroleum. Bio-oil can be used directly when attached to industrial oil-fired boilers and internal combustion engines.

2.16.3.2. Gasification

Gasification is a hydrothermal process of converting the organic components of MSW through partial oxidation into a gaseous mixture of syngas comprising hydrogen (H2), carbon monoxide (CO), methane (CH4) and carbon dioxide (C02) (Yakaboylu *et al*., 2015). The organic MSW feedstock undergoes gasification under varying temperatures and pressure or in the presence of oxidant or gasification agents, which can be air, pure oxygen, steam, carbon dioxide or a mixture of these agents (Wang et al., 2008). Air is the most widely employed oxidant and the cheapest, but it contains a large amount of nitrogen, which lowers the heating value of the syngas produced. The pure oxygen agent improves the heating value of the syngas; however, this comes at a high cost and will increase with the production of pure oxygen. Applying partial combustion with air or oxygen provides the necessary heat for drying the MSW, increasing the temperature of the feedstock, driving the endothermic gasification reactions, and generating water and carbon dioxide for further reduction reactions (Ahmad *et al*., 2016). Further steam as a gasification agent can increase the syngas' heating value and hydrogen content (Kaushal & Tyagi, 2012).

Figure 0.15 *A Typical Gasification Process*



Note: from (Kumar *et al*., 2020)

Three major types of gasifiers have been identified in the literature: fixed bed, moving bed, and fluidised bed gasifiers (Ahmad *et al*., 2016). The fixed bed and moving bed gasification technologies have more straightforward and more reliable designs and are better suited for MSW with high moisture content (Wang *et al*., 2008; Ahmad *et al.,* 2012) to generate syngas with high tar or char content. They subject the feedstock to low and non-uniform heat and mass transfer between solid MSW and gasification agents. The fluidised bed gasification offers a more uniform heating and higher productivity than the other two options (Ahmad *et al.,* 2016).

Freitas and Guirardello (2014) noted that supercritical water gasification has advanced to become a more efficient technology for producing fuel gas from organic sources. The apparent advantage of supercritical water gasification is the ability to convert energy from MSW without requiring a high energy-consuming drying process to obtain higher energy efficiency (Yakaboylu *et al.*, 2015). The by-products of this technology contain minimal air pollutants, such as nitrogen and sulphur, as supercritical gasification occurs at relatively low temperatures (Jin *et al*., 2014). Further catalysts can be introduced to lower the temperature and simultaneously accelerate the reaction to ensure the economic and technological efficiency required to obtain the desired products (Azadi & Farnood, 2011).

2.16.4. Biochemical Conversion

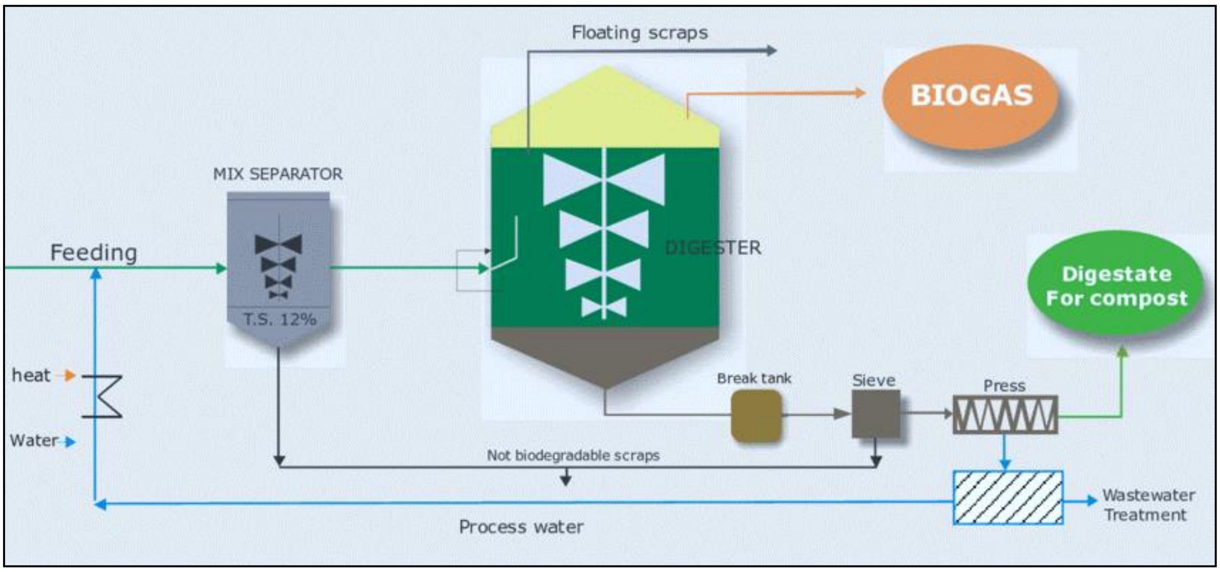
Biochemical conversion is the process of using bacteria, microorganisms, and enzymes to decompose MSW materials into liquid and gaseous fuels such as biogas, ethanol, acetone, butanol, and organic acids, hence providing the platform substances for the conversion of renewable materials, fuels, and chemicals (Devi *et al*., 2014; Mahalaxmi & Williford, 2014). Biochemical conversion has a significant advantage over thermal and thermochemical conversion technologies as it is purer, cleaner, and more efficient (Devi et al., 2014; Lee et al., 2019). However, on the downside, the biochemical process requires pre-processing stages, a longer conversion process, and complex downstream processing, such as distillation, that can be energy-intensive (Lee *et al*., 2019). Biochemical technologies include anaerobic digestion and fermentation (Brethauer & Studer, 2015).

2.16.4.1. Anaerobic Digestion

Anaerobic digestion is a natural biological process that is essential for sustainable MSWM and generating renewable energy (Zaman & Reynolds, 2015); this is achieved through a multiple-step process that stabilises organic MSW in the absence of air and transforms it into biofertilizer and biogas (see Figure 2.14). These multiple steps include hydrolysis, acidogenesis, acetogenesis and methanogenesis (Horan *et al*., 2018). In each process, the organic MSW is subjected to chemical reactions from natural metabolic pathways enabled by microorganisms in an oxygen-free environment (Sharma, 2015; Zaman & Reynolds, 2015). Hydrolysis represents the initial phase of the process – with the MSW, mainly the organic fraction, converted into smaller molecules such as fatty acids, simple sugars, and amino acids. In the second stage (acidogenesis), the larger molecules from the MSW feedstocks are further decomposed to produce NH_3, CO_2, H_2, H_2S, alcohols, lighter volatile fatty acids, carbonic acids, and alcohols. In acetogenesis, the products from the acidogenesis are decomposed into acetic acid (CH_3COOH), CO_2 and H_2. Lastly, in methanogenesis, the products from acetogenesis are broken down to produce biofuel and digestate through hydrogenotrophic methanogenesis.

The biogas from anaerobic digestion can generate electricity and heat, providing a renewable substitute for natural gas and transportation fuel (Xu *et al*., 2018). A combined heat and power plant system (CHP) generates power. It produces heat for in-house requirements to maintain the desired temperature level in the digester during the cold season (Sowmya *et al*.,2020). In Sweden, compressed biogas is used as a fuel for cars and buses (Ahlberg-Eliasson *et al*., 2017). Digestate can be further processed to produce liquor and a fibrous material (Xu *et al*., 2018; Sowmya *et al.,* 2020). The fibre, which can be processed into compost, is a bulky material with low levels of nutrients and can be used as a soil conditioner or a low-level fertiliser. A schematic presentation of the anaerobic digestion process is shown in Figure 2.14.

Figure 0.16 *Anaerobic Digestion Process*

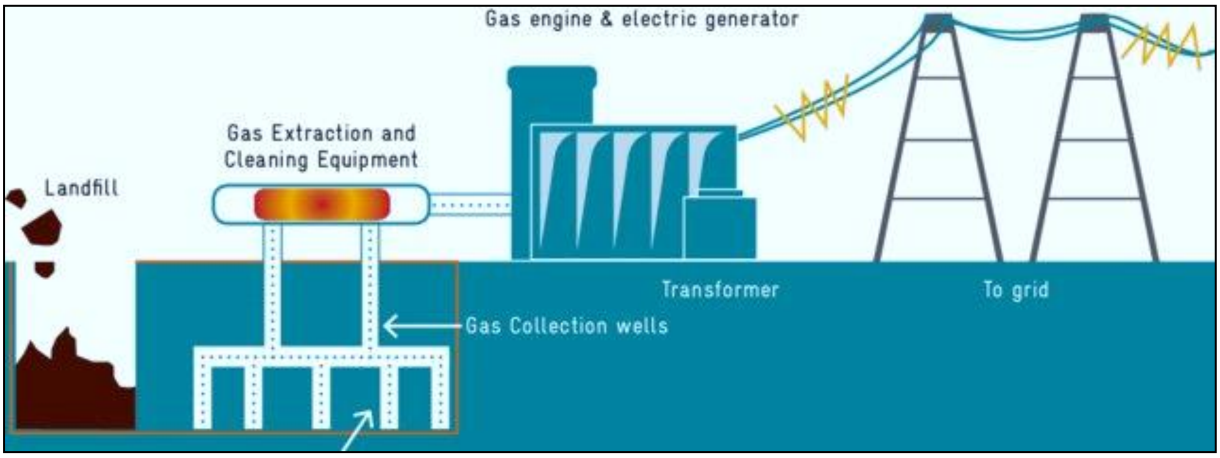


(*Note*: from Mainero, 2008)

2.16.5. Landfill Gas Recovery Systems (LFGR)

Generally, landfills play a pivotal role within urban waste management systems, even in cases where alternative waste disposal methods are employed; this significance remains constant across cities with high recycling rates or substantial reliance on incineration (Kaza & Bhada-Tata, 2018). Therefore, despite the increasing development of waste technologies, the use of landfills in both developed and developing countries may likely not end soon. Over the last two decades, LFGR technology has experienced continuous advancement. Developed nations have made notable strides in converting LFG into diverse forms of energy. However, as the European Union actively pursues strategies to curtail MSW generation, which will decrease the amount of MSW disposed of in landfills, its utilisation may decrease (Njoku *et al*., 2018).

Figure 0.17 *Typical Landfill Gas Recovery System*



(*Note*: from Mutz *et al*., 2017)

LFGR systems present an opportunity to mitigate landfills' environmental effects. This process involves compaction, moisture control, and leachate exclusion, with daily soil cover application to minimise pollution and disease transmission (Kabir *et al*., 2022). Hence, constructing sanitary landfills with impermeable liners crafted from materials like clay or polyethene can effectively prevent leachate contamination of groundwater. According to Njoku *et al*. (2018), in developed countries like Germany and Sweden, LFGR systems are used to power trains and generate home electricity using biogas. Using Malaysia as a case study, it was projected that between 2015 and 2020, around 310,220 tonnes of methane per year were produced by landfills due to MSW, and through the utilisation of LFGR technologies, approximately 1.9 billion kWh of electricity were generated from these resources, meeting about 1.5% of Malaysia‘s energy demand (Noor *et al*., 2013; Song *et al*., 2020). However, LFGR utilisation techniques remain relatively novel in Africa due to limited expertise, economic constraints, and a lack of proactive governmental support for LFG utilisation on the continent (Kaza & Bhada-Tata, 2018), despite mounting municipal solid waste (MSW) generation driven by population growth and industrial expansion and its suitability for the region.

2.17. Advantages and disadvantages of WtE:

The main advantages of Waste-to-Energy (WtE) include:

Reduction of Landfill Waste: WtE can significantly reduce the volume of waste sent to landfills. It can decrease waste by up to 87%, converting 2,000 pounds of garbage into just 300 to 600 pounds of ash. This reduction is crucial as landfills contribute to greenhouse gas emissions, mainly methane, which is about 25 times more potent than carbon dioxide over 100 years (Olukanni & Nwafor, 2019).

Energy Generation: WtE facilities generate renewable energy, which can help reduce reliance on fossil fuels. This energy can power homes and industries, creating a more sustainable energy mix. By harnessing energy from waste, WtE supports a circular economy, where waste is viewed as a resource rather than merely a disposal issue (Sinthumule & Mkumbuzi, 2019).

Greenhouse Gas Emissions Reduction: While WtE produces carbon dioxide, it does not generate methane, making it a preferable option to landfilling. The emissions from WtE are generally lower than those from landfills, as the latter release both carbon dioxide and methane during waste decomposition (Liddle, 2017).

Resource Recovery: WtE facilities can recover valuable resources, such as metals, from the ash after incineration. These materials can then be sent for recycling and kept in the economy; this is even true of mixed materials, which are hard to recycle. Incineration burns away materials such as plastics, leaving the metals behind, which can be better than landfills where recyclable materials are buried.

Compatibility with Recycling: U.S. counties and municipalities that employ WtE for non-recyclable waste materials consistently have increased recycling rates compared to communities without WtE plants; this suggests that WtE can complement recycling efforts by handling waste that cannot be easily recycled. While WtE presents several advantages, it is most effective when integrated into a broader waste management strategy prioritising waste reduction, recycling, and composting (World Bank, 2021). The environmental impact of WtE must be carefully weighed against other strategies to ensure that it contributes positively to sustainability goals rather than undermining them.

Criticisms: Waste-to-Energy (WtE) has garnered support and criticism as a waste management strategy. The main criticisms of WtE primarily revolve around environmental concerns, economic viability, and its impact on recycling efforts (Adama, 2012; Alabi, 2021; Boateng *et al*., 2019; Kadafa, 2017). Here are the key criticisms:

- **Air Pollution:** WtE facilities can emit pollutants, including dioxins, heavy metals, and particulate matter, posing health risks to nearby communities. Critics argue that the combustion process, even with modern filtration technologies, can still lead to harmful emissions that affect air quality.

- **Greenhouse Gas Emissions:** Although WtE reduces landfill use and methane emissions associated with decomposing waste, it still produces carbon dioxide and other greenhouse gases during combustion; this raises concerns about its overall contribution to climate change, especially when compared to more sustainable waste management practices like recycling and composting (Adama, 2012).

- **Destruction of Recyclable Materials:** WtE can lead to the incineration of materials that could otherwise be recycled. Critics argue that this practice undermines recycling efforts and disincentivises the development of more sustainable waste management solutions. The concern is that reliance on WtE may diminish the motivation to improve recycling systems.

- **High Operational Costs:** Establishing and operating WtE facilities can be expensive. The infrastructure required for WtE plants and the ongoing operation costs can lead to financial challenges, particularly in regions with lower waste calorific values, where additional energy may be needed to incinerate waste effectively (Alabi, 2021; Boateng *et al*., 2019).

- **Dependence on Waste Generation:** WtE facilities require a consistent and substantial waste supply to operate efficiently. This dependency can create a paradox where the incentive to minimise waste generation is reduced, potentially leading to increased waste production to keep the plants viable (Alabi, 2021).

- **Competing with Recycling Initiatives:** Critics argue that establishing WtE plants may divert attention and funding from recycling and composting initiatives. By providing an alternative disposal method, WtE could undermine efforts to enhance recycling rates and reduce overall waste generation.
- **Quality of Waste Input:** Many WtE facilities struggle with poor-quality waste inputs, often mixed and unsegregated materials; this can lead to operational inefficiencies and increased emissions, as not all waste is suitable for burning. In some cases, the plants may require supplementary energy to operate effectively, further complicating their economic viability (Debrah *et al.*, 2022).

2.18. Assessment Techniques for MSWM Strategies

The MSWM models discussed so far all maintain the primary objective of improving the quality of human life, protecting against environmental degradation, and conserving natural resources by encouraging sustainable practices. In addition, these models each highlighted the critical role of the different decision-makers (stakeholders) in developing a sustainable MSWM system viable within a local context. Rogge and De Jaeger (2012) argue that selecting a fit-for-purpose MSWM model borders two main questions: “(i) if the current waste management system provides the most cost-effective method for reaching the goals of MSWM; and (ii) if there other and better combinations of more advanced processes that can provide an identical service at lower costs”. Further, Allesch and Brunner (2015) conducted a literature review of different assessment methods and identified 11 assessment methods to help select the suitable model. However, for this study, the focus is primarily on five, vis-a-vis: (i) cost-benefit analysis, (ii) cost-effectiveness analysis, (iii) life cycle costing, (iv) life cycle assessment and multi-criteria decision-making.

2.18.1. Cost-Benefit Analysis

The Cost-Benefit Analysis (CBA) is founded on the theoretical underpinning that benefits are measured by increased human well-being (utility). In contrast, cost is a measure of reduction in human well-being (Pearce *et al.,* 2006). Monetary and physical values measure all benefits (Chang *et al*., 2012). From the MSWM perspective, cost estimates include capital operation and maintenance costs (Jamasb & Nepal, 2010; Chang *et al.,* 2012). The capital costs encompass the cost of civil works and mechanical equipment.

In contrast, operational costs include annual labour, power, and fuel expenses, with maintenance costs as a percentage of the capital cost (Yuan *et al*., 2011). The capital, operational and maintenance costs are determined as a function of the annual generation of MSW. Yuan *et al.* (2011) examined the dynamics and interrelationships of construction and demolition waste management practices, analysed the cost-benefit of this process in Shenzhen, and reported net benefits from conducting construction and demolition waste management. A higher net benefit and realisation of the net benefit were reported when there was an increase in the landfill charge.

Jamasb and Nepal (2010) investigated the social cost-benefit analysis of WtE in the UK regarding economic and environmental aspects. Their findings indicated that meeting the waste management targets of the EU directive is socially more cost-effective – this improves substantially with higher carbon prices. Elagroudy *et al*. (2011) examined the environmental, economic, and technical aspects of different MSW scenarios to assess the options available for MSWM in Basrah City, i.e. (i) direct waste disposal into a sanitary landfill, (ii) waste transportation to transfer station and then to a sanitary landfill; and (iii) sorting, recycling, and composting followed by landfill disposal in an integrated treatment disposal facility. The findings from the study showed that cost-benefit analysis favoured the third option not from the economic perspective (the revenues generated from selling the produced recyclables and compost) but from an environmental perspective – based on the positive recognition of the diversion of waste to recycling.

The evidence from the literature indicates that CBA enables decision-makers to assess the positive and negative effects of a set of scenarios by translating all impacts into standard measurement, usually monetary; this implies that impacts which do not have a monetary value, such as environmental impacts, must be estimated in monetary terms. There are several ways to do this, such as estimating the costs of avoiding a negative effect (e.g., the cost of pollution control on an incinerator) or establishing how much individuals are willing to pay for an environmental improvement. Social impacts can also be evaluated in the same way, although social impacts were not included in any of the MSWM systems. Minimum cost is a criterion for selecting the most economical, environmental, and socially acceptable scenarios. However, environmental impacts and benefits may divert the recommendations towards sustainability, which is currently more desired by societies seeking long-term environmental benefits and conserving natural air, water, and soil resources.

2.18.2. Cost-Effectiveness Analysis (CEA)

The CEA examines the costs and health outcomes of one or more interventions (Levin & McEwan, 2003; Muennig & Bounthavong, 2016). It compares interventions (or the status quo) by estimating how much it costs to gain a unit of a health outcome like a life-year gain or death prevented (Muennig & Bounthavong, 2016). Like CBA, CEA allows policymakers to evaluate the trade-offs between alternative interventions and obtain the most effective given the available resources. (Chang *et al.* 2012). In MSWM terms, cost-effectiveness analysis helps identify and place monetary values on the costs of interventions for specific programs. Drobny *et al*. (1971) theorised two approaches to CEA. The first approach requires the direct cost analysis (including capital and operating cost estimates) of all significant components of the systems, and the second approach involves evaluating the effectiveness of each system component after considering multiple options.

Similarly, Philips (2005) argues that CEA requires distinction must be made between completely independent and mutually exclusive interventions. Independent interventions represent situations where the costs and effectiveness of one model are unaffected by the introduction of another model. A mutually exclusive perspective implies that introducing a new model changes the costs and effects of the original model. In MSWM, wastes are valued from both economic terms (valuable goods or services) and public health perspectives that should provide value to society, irrespective of the market interest in its usage in the manufacturing cycle or the willingness of the people or users to pay for it (Philips, 2005; Barnett, 2009; Gradus *et al.,* 2017). In essence, city authorities must remain strong in the provision of such services as well as in administration through policies and legislation (Wilson et al., 2012; Gradus et al., 2017).

2.18.3. Life Cycle Assessment

Life Cycle Assessment (LCA) focuses on the environmental aspect of MSWM and the potential implication of waste generation on natural resources and environmental consequences of waste materials throughout the product's life cycle, i.e., from acquiring raw material to manufacturing, product usage, end-of-life treatment, recycling, and final disposal (Khandelwal *et al*., 2019). The LCA is structured to consider inputs and output at the different stages of the product life cycle and, in addition to evaluating all factors, including global warming potential (GWP), acidification, and ozone depletion; as such, LCA is inevitably a complex analysis (Coelho & Lange, 2018; Khandelwal *et al.,* 2019). In an MSWM system, the LCA is used to compare different disposal practices and quantify context-specific environment and public health impacts, reducing the harmful impacts of MSW (Yadav & Samadder, 2017). One of the significant strengths of the LCA is that it considers the local context in modelling MSWM systems (Chen & Lin, 2008; Torkayesh *et al*., 2022).

A typical LCA process has four interrelated phases: goal and scope definition, life cycle inventory analysis, identification of inputs and outputs for each process or material, life cycle impact assessment, and interpretation (Yadav & Samadder, 2018). System boundaries are central to the LCA process, which define the scope of the analysis and determine which processes and materials are included in the assessment.

Recent studies have investigated the application of the LCA process on solid waste management strategies in both developed and developing countries. The general evidence from these studies shows that landfilling with little or no material recovery for recycling and composting has the most decisive negative environmental impact. In contrast, incineration plus energy recovery MSWM strategies contribute minimally to emissions of greenhouse gases and acidification that is critical to the environment and human health (Maalouf & El-Fadel, 2019; Rishi *et al.,* 2019; Mohammad *et al.,* 2019). Ferronato *et al.* (2020) performed an LCA assessment of MSWM systems in Bolivia and reported that flaring landfill gas allows for a reduction in the GWP and increasing acidification potential (AP). The authors reported that open waste burning increases the human toxicity potential (HTP), the GWP, and the AP. In contrast, recycling and energy recovery allow for the reduction of just about all environmental impacts.

Coelho and Lange (2018) explored sustainable waste management strategies for Rio de Janeiro, Brazil, utilising the Life Cycle Assessment (LCA) methodology. Their research focused on evaluating different waste treatment options to identify the most environmentally sustainable approach for the city‘s waste management. Through their LCA analysis, the researchers assessed various waste treatment technologies, considering their environmental impacts throughout their life cycle. They specifically examined the involvement of anaerobic digestion (AD) in combination with recyclable material recovery. The study's findings indicated that integrating anaerobic digestion and recyclable recovery presented the most environmentally sustainable waste management option for Rio de Janeiro.

In a Nigerian context, Ayodele*et al*. (2018) and Nubi *et al*. (2022) used an LCA in their economic and environmental assessment of electricity generation using biogas from an organic fraction of MSW for the cities of Ibadan and Abuja, respectively. Given the environmental parameters assessed, the authors concluded that AD is more viable than LFGR and incineration in both states. Evidence from these studies validates the possibility of improving MSWM processes by decreasing harmful waste emissions that negatively impact the environment and human health and increasing energy recovery, thereby fostering the sustainability of natural resources.

2.18.4. Life Cycle Costing

Life Cycle Costing (LCC) is an economic analysis method that, when combined with LCA, provides a comprehensive approach to evaluating the financial and environmental implications of products or systems throughout their entire life cycle (Sharma & Chandel, 2021). Tan et al. (2015) provided an example of its application. The researchers conducted energy, economic, and environmental analyses for four WtE schemes in Malaysia. They revealed incineration as the preferred choice when heat and electricity production benefits were considered. However, anaerobic digestion was superior when only electricity production was considered.

Similarly, in India, Sharma and Chandel (2017) compared six different scenarios for MSW management strategies in Mumbai City, India, using the LCA approach. The scenarios included landfill with biogas collection, incineration and different combinations of recycling, landfill, composting, anaerobic digestion, and incineration. The study concluded that combining recycling, composting, anaerobic digestion, and landfilling recorded the lowest overall environmental impact. Incineration reduced global warming because the GHG emissions were avoided, although human toxicity increased. Furthermore, Babu *et al.* (2014) considered four scenarios for Bangalore City, India: open dumpsite, landfill without gas recovery, landfill with gas recovery and bioreactor landfill. A bioreactor landfill gas recovery system was economically and environmentally better than other scenarios, while open dumping was the least preferred option.

2.18.5. Multicriteria Decision Analysis (MCDA)

Another standard tool decision-makers use in MSWM is the Multi-criteria decision analysis (MCDA) (Soltani *et al*., 2015; Mir *et al.,* 2016). The MCDA is a decision-making tool that facilitates choosing the best alternative. This tool evaluates a problem by comparing and ranking different options and evaluating their consequences according to established criteria (Hung *et al.*, 2007; Karmperis *et al.*, 2013). MCDA helps in the decision-making process and helps decision-makers in complex decision situations involving multiple criteria arising from economic, social, and environmental considerations (Sharma *et al*., 2015). Hence, the main goal of MCDA is to concentrate on decision analysis within a finite set of alternatives and offer a technique to help decision-makers make decisions. It proposes two unique features for handling decision problems: preference-based aggregation and the ability to handle both quantitative and qualitative criteria (Cinelli *et al*., 2022).

Various researchers have introduced different approaches to MCDA, such as Kaaney and Raiffa's Multi-Attributes Utility Theory (MAUT) (1976), Roy's outranking methods (1996), and Saaty's Analytical Hierarchy Process (AHP) (1980). Among these methods, AHP is the most commonly used for analysis (Torkayesh *et al*., 2022). According to Vlachokostas *et al*. (2021), in the context of WtE decision-making, the AHP process may involve several steps: first, important evaluation criteria, such as efficiency, cost-effectiveness, environmental impact, scalability, and social acceptance, are defined. Then, these criteria are organised into a hierarchical structure with the overall objective at the top, criteria in the middle, and WtE technology alternatives at the bottom. According to the researchers, this is followed by pairwise comparisons to assess the relative importance or performance of criteria and alternatives. Based on these comparisons, priority weights are calculated for each criterion and alternative. A consistency check is then conducted to ensure the logical coherence of the comparisons. Finally, the priority weights are aggregated, and WtE technologies are ranked based on suitability, helping decision-makers make informed choices for technology selection.

In a recent study by Alam *et al*. (2022) conducted in Bangladesh, MCDA and AHP were applied to evaluate and select Waste-to-Energy technologies based on technical, economic, environmental, and social criteria. The study aimed to identify Bangladesh's most suitable WtE technology, considering its unique challenges and opportunities. Using AHP, the researchers ranked the WtE technologies under consideration, which included Anaerobic Digestion (AD), Landfill Gas Recovery (LFGR), gasification, and incineration. Considering the technical, economic, environmental, and social factors relevant to the context, the study concluded that AD was the most suitable WtE technology for Bangladesh. This outcome indicates that AD presented the best balance of performance across various criteria compared to the other technologies considered.

2.19. Chapter Summary

This chapter has provided an in-depth analysis of the literature relevant to the research questions posed in this study. It has explored various aspects of waste management, including key concepts and practices, barriers and highlighted technological options. Among the key gaps identified is the lack of up-to-date and accurate waste management data highlighting the social aspects of waste management in Nigeria. The chapter further reviewed some of the critical MSW models, including the assessment techniques for the viability of the MSWM system. The literature review has laid the foundation for the subsequent chapters, contributing valuable insights and perspectives to understanding waste management issues in the context of this study. The next chapter provides a detailed discussion of the research methodology adopted to achieve the aim and address the research questions.

Chapter 3: Research Methodology

3.1. Introduction

The term 'research' is related to seeking information on a particular topic or subject to gain new knowledge from existing facts (Bairagi & Munot, 2019). It is considered an art of systematic investigation. Hence, a research methodology is a body of knowledge that enables researchers to explain and analyse methods, indicating their limitations and resources, identifying their assumptions and consequences, and relating their potentialities to research advances (Miller & Miller, 2000). The issue of waste management, specifically in Nigeria, is a real-life social problem with a wide-ranging perspective overlapping multiple academic and social sciences, and this overlapping scope often requires the use of finite statistical information and general knowledge of the subject area. Waste management is one of many interconnected public services for community well-being; consequently, it is best understood from a holistic viewpoint that includes various municipal and high-level governmental institutions and community values and behaviours (Keske *et al*., 2018).

The literature review provided an overview of waste management challenges and barriers faced in developing countries, including those reported in Nigeria. With growing interest in adopting WtE technologies to solve Nigeria's rapidly increasing waste quantities, this study examines the challenges, barriers and prospects of waste management in the country's capital city, Abuja. It follows municipal solid waste from generation to treatment and disposal. Thus, the practical research adopted a multifaceted process of experimentation, investigation, and inquiry to generate a focal starting point to guide decision-makers in adopting strategies and policies that would enable the implementation of WtE technologies.

This chapter introduces the methodology employed for this study. It outlines and justifies the research design and methodology to fulfil the research aim and questions. This chapter describes and justifies the research methodology construct with an in-depth review of the research philosophy, approach, and strategy. The logical description is then followed by the research design, which highlights the techniques, research instruments, statistical methods, and ethical guidance followed in conducting the research.

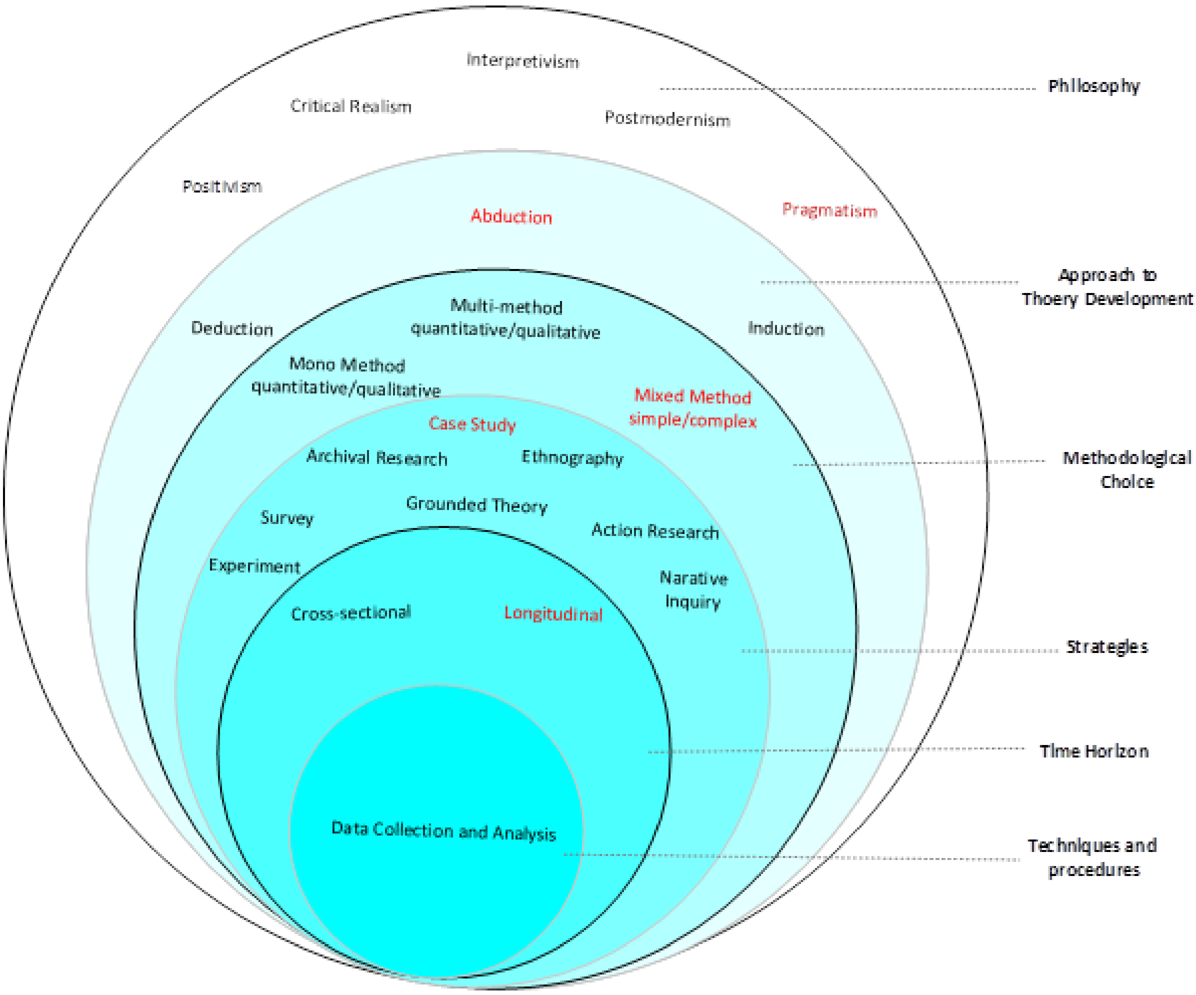
3.2. Research Methodological Framework

Research generally describes the process followed by a researcher to achieve the aims and objectives of a particular study systematically. This process may include the use of a variety of methods. Before exploring further, it is important to clarify the difference between research methodology and research methods. Blumberg, Cooper, and Schindler (2014) state that research methods provide the researcher with adequate ideas, tools, and models that demonstrate how to conduct research. The authors agree with Greener (2008) that while research methods are about data collection instruments such as questionnaires, interviews, and focus group discussions (FGDs), research methodology is about research perspectives, approaches, beliefs, and philosophies. Hence, the research method is narrower in scope and is a methodology component.

Ghauri and Grohaug (2020) emphasise that research methodology is an essential framework of directives and protocols for multifarious reasons. These can be interpreted, for instance, as rules of communication, where the processes and procedures employed in the research are shared with other researchers for review or replication. When selecting a research methodology, the researcher must be conversant with the philosophical underpinning and be able to explain and defend this stance confidently and clearly (Easterby-Smith *et al*., 2008). Moreover, the research model implements the steps taken throughout the research and is typically used as a guide for researchers so that they are more focused on the scope of their studies.

The research methodology construction for this study is based on the theoretical concept of the “research onion” (See Figure 3.1), proposed by Saunders *et al*. (2016, p. 164). Using this concept, the authors outline the research philosophy, research approach, research strategies, time horizon, and research techniques/methods in a way that denotes a systematic direction and the cohesion of constituent elements to represent a paradigm of research methodology.

Figure 0.18 *The Research Onion*



(*Note*: Adapted from Saunders *et al*., 2016, p. 164)

The research philosophy, the outer layer of the research onion methodological process, births and motivates the other layers of the paradigm, such as the research methodologies and strategy that work with the research techniques and procedures to accomplish a research aim and objectives. The next sections of this chapter are structured to follow the 'Research Onion Framework', from the outer layer, which describes the research philosophy, down to the last layers covering the data collection and analysis.

3.2.1. Research Philosophies and Assumptions

A traditional research methodology is founded on a particular philosophical stance, which then dictates the research's techniques and methodologies (Nweke & Orji, 2009; Saunders *et al*., 2016). Understanding the philosophy is important as it often encourages in-depth thinking and generates further questions in relation to the topic under consideration (Crossan, 2013). Easterby-Smith *et al.* (2012) suggest that the exploration of philosophies, also referred to as 'paradigms' (Lincoln *et al*., 2011) in research methodology may be significant because it may encourage the researcher to be creative and imaginative in choosing or adaption methods and enable and aid the researcher in evaluating alternative techniques and procedures and avoiding improper application and extra labour by identifying the limitations of specific approaches early on. The researchers also established that it can aid the researcher in refining and defining the research methodologies to be employed in a study, elucidating the overall research approach by including the type and source of the evidence obtained, its interpretation, and its contribution to answering the study questions provided. They concluded by emphasising that failure to include philosophical considerations in a study design might harm the quality of the research result.

Positivism, interpretivism, pragmatism, postmodernism and realism are highlighted by Saunders *et al*. (2016) as the predominant research philosophies (See Table 3.1 for definition of concepts). These paradigms differ and, thus, are distinguished by the types of assumptions they make. Therefore, the basis of the research is formed by the delineation of ontological, epistemological, and axiological assumptions (Melnikovas, 2018), which shape the researcher's understanding of the research design, including the research questions, methods applied and the interpretation of findings (Saunders *et al*., 2016). These assumptions are highlighted in the following sections to provide the foundation for comprehension of the philosophical perspective taken in this study.

Table 0.6 *Research Philosophies and Concepts*

Philosophy	**Concept**
Positivism	Relates to the philosophical stance of the natural scientist and entails working with an observable social reality to produce law-like generalisations
Interpretivism	Emphasises the thought that humans are different from physical phenomena because they create meanings
Pragmatism	Asserts that concepts are only relevant where they support action
Postmodernism	Emphasises the role of language and power relations, seeking to question accepted ways of thinking and give voice to alternative marginalised views

Realism	It focuses on explaining what we see and experience regarding the underlying structures of reality that shape the observable events.

(*Note*: Adapted from Saunders *et al*., 2016)

3.2.1.1. Ontology

The ontological assumption claims what kinds of social phenomena exist, how they come to exist, and their relationship (Blaikie, 2011). Hence, it refers to the researcher's belief about the nature of reality (Killam, 2013). Two contrasting ends are significant to adopting the research paradigm: the researcher's influence on the research outcome, subjectivism, and the researcher's independence in executing field work, objectivism (Aliyu *et al*., 2015). Melnikovas (2018) states that ontology, in the view of a positivist, is based on the objectivist belief that entities are observed, atomistic occurrences that exist external to social actors; hence, only observation and empirical evidence may be considered "credible." However, an interpretivism approach is based on a subjectivist ontological assumption that knowledge and facts are relative since entities are made up of discourse; therefore, existent or socially created reality can only be studied through social constructs such as consciousness or language (Melnikovas, 2018; Myers, 2008).

3.2.1.2. Epistemology

Epistemology, the second assumption, is intimately linked with ontology and is one of the most important branches of philosophy which examines the theory of knowledge, especially in terms of how it is gained, how it can be proven, and how many ways there are to learn about social reality and its meaning (Grix, 2018). Epistemological assumptions are reflected in the theoretical perspectives, methodology, and methods of research studies; in other words, depending on a researcher's beliefs about what can be known (ontology) and how to approach coming to know it (epistemology), different decisions will be made toward designing an effective study (Hiller,2016).

Siddiqui (2019) states that positivism's epistemological assumption, realism, maintains that meanings exist inside entities as objective truths independent of the human mind; this implies that to prevent or minimise researcher bias, researchers should endeavour to separate themselves from the investigated reality and separate themselves from the subjects being examined. Siddiqui further stresses that, according to positivists, the researcher aims to explain reality by objective observation, verification, and measurement. In contrast, interpretivism epistemology is the study of the interconnection between the research and the research subject, and it is more concerned with the meaning, voice, standpoint, experience, thoughts, and feelings expressed by the individual (Junjie & Yingxin, 2022; Moustakas, 1994).

3.2.1.3. Axiology

Axiology, the third and final assumption, describes the importance of value and ethics in research (Saunders *et al*., 2016). In addition, it describes how researchers deal with values and how the study participants are valued. Heron (1996) noted that our values are the driving force behind all human behaviour. Sauders (2016) believes that Heron's argument means researchers display axiological competence by being able to express their values as a foundation for making decisions regarding the research they perform and how they conduct it. Hence, it clarifies how values or decisions might influence the researcher‘s judgment. According to Saunders, the influence of a researcher's experience can either be value-free or value-bound. He explains that it is value-free when the study incorporates an objective contribution of the researcher‘s thoughts or experiences (Objectivism). However, it is value-bound (Subjectivism) when the researcher considers their sentiments, personal values, beliefs, or prior experiences. However, the author emphasises that the axiology assumption, like the other two assumptions, should be identified in relation to objectivism and subjectivism in terms of value-free and value-bound. Table 3.2 summarises the assumptions in relation to the philosophies. The following section justifies the philosophy adopted by the researcher for this study.

Table 0.7 *Philosophies and Assumptions*

Philosophy	Ontology	Epistemology	Axiology
Positivism	Real, external, independent One true reality	Scientific method Observable and measurable facts Law-like generalisations numbers	Value-free research The researcher is detached, neutral and independent of what is researched The researcher maintains an objective stance
Interpretivism	Complex, rich Socially constructed through culture and language	Theories and concepts too simplistic Focus on narratives, stories, perceptions, and interpretations	Value-bound research Researchers are part of what is researched, subjective Researcher interpretations key to the contribution
Pragmatism	Complex, rich, external 'Reality' is the practical consequences of ideas The flux of processes, experiences and practice	Practical meaning of knowledge in specific contexts Focus on problems, practices and relevance Problem-solving and informed future practice as a contribution	Value-driven research Research initiated and sustained by the researcher's doubts and beliefs Researcher reflexive
Postmodernism	Nominal, Complex, rich Socially constructed through power relations Some meanings, interpretations, and realities are dominated and silenced by others	What counts as 'truth' and 'knowledge' is decided by dominant ideologies Focus on absences, silences and oppressed/ repressed meanings, interpretations and voices	Value-constituted research Researcher and research embedded in power relations Some research narratives are repressed and silenced at the expense of others
Realism	Stratified/layered (the empirical, the actual and the real) External, independent Intransient Objective structures Causal mechanisms	Epistemological relativism Knowledge historically situated and transient Facts are social constructions Historical causal explanation as contribution	Value-laden research The researcher acknowledges bias based on world views, cultural experience, and upbringing. Researcher tries to minimise bias and errors The researcher is as objective as possible

Note: Adapted from Saunders *et al*. (2016)

3.2.1.4. Adopting a Pragmatic Stance

Waste management research's complexity and broad nature require multiple views, perspectives, and standpoints to understand its reality. Therefore, this study is underpinned by pragmatism with a non-singular reality ontology (Kivunja & Kuyini, 2017) and accepts that single or multiple realities can open to empirical inquiry (Creswell & Clark, 2017). The pragmatic approach advocates various data collection tools (Alturki, 2021). Using various methods (mixed methods) and data sources, the study focused on WM challenges and barriers aimed at contributing practical solutions that inform future WM developments. Although Barret (2010) considers critical realism to be the foundation of mixed methods research, critics like Denscombe (2007) and Knight & Ruddock (2009) argue that the mixed method is more rooted in pragmatism. Despite these arguments, this research was more interested in practical outcomes than abstract distinctions and has considerable variation in how objectivist or subjectivist it turns out to be (Saunders, 2016). Furthermore, Hesse-Biber and Johnson (2015, pg. xxxv) state that a pragmatic standpoint would ask, “What is needed to answer the research question?”. The authors argue that in answering this question, a pragmatist does not focus on the epistemological perspective for guidance but instead seeks the best method or methods for addressing the research question. The final justification is the value-laden axiology, in that the outcome of this research is aimed at benefitting people. As a research paradigm, pragmatism orients itself toward solving practical problems in the real world.

3.2.1.5. Positionality Statement

Positionality statements allow researchers to reflexively highlight their frame of reference, personal bias and other factors that may impact their research findings (Secules et al., 2021). For this research, I consider myself an outside researcher as I am not actively a resident of Abuja, Nigeria, nor a stakeholder in Abuja's waste management sector. I identify as a young, multilingual, non-disabled, heterosexual, married male of African ancestry. Growing up in a diverse environment, I adapted to multilingual surroundings, which cultivated proficiency in several local languages, aside from my knowledge of the English language. This formative, diverse environment firstly informed my mixed methods approach to this research, and my multi-linguistic abilities enabled me to engage with the research setting and comprehend their perspectives on waste management challenges and prospects. However, I was conscious that my outsider status also impacted my understanding of the local context and nuanced dynamics during my research enquiry.

In working with stakeholders in Nigeria, I actively engaged public and private sector workers of experienced operational staff from AEPB, private contractors working with the government agency, and representatives from the local council (AMAC) and the Federal Ministry of Environment. Their contributions helped shape the research findings and provided context-specific insights. The role of these stakeholders provided several advantages or additional value. For example, public sector workers from AEPB and the Federal Ministry of Environment provided insights into Abuja's regulatory framework, policy directions, and operational challenges associated with waste management. Representatives from the local council (AMAC) played a crucial role in bridging the gap between national policies and local implementation strategies. Their input helped contextualize the research within Abuja's specific socio-economic and environmental dynamics, ensuring the findings are context-specific.

The involvement of stakeholders in the research process played a pivotal role in ensuring its relevance, validity, and ethical conduct. Stakeholder participation fostered a collaborative approach, enhancing the validity of the findings while promoting the local community's voice. However, I acknowledge that it is possible that specific stakeholders, while providing insight into my research, may have created narratives that suit their personal or political ideologies or affiliations for waste management, resulting in subjective, non-generalisable perspectives. The quantitative phase sought to compensate for the subjective perspectives that may have been obtained from stakeholders.

3.2.2. Research Approach

The approach to theory development is the second layer of the onion model this study follows, as proposed by Saunders *et al*. (2016). According to Creswell (2014), research approaches are the general methods applied in the research process, from the theoretical context to data collection and analysis. Hence, the research approach describes plans for finding and evaluating information. Malhotra (2017) proposes four key stages of a research strategy as follows:

1. The analysis of the major concepts of the topic
2. Defining the relevant keywords and their synonyms
3. Searching the relevant databases and sources
4. Analysing the quantity and relevance of the information obtained

Research approaches may have limitations (Creswell (2014), for example, the time-consuming nature of inductive research or the false assumption by deductive research that all disciplines in natural sciences function in the same way (Hammond, 2016). Despite these limitations, Easterby-Smith *et al*. (2012) argue that a research approach is vital since it guides the researcher through data collection, data sources, and how evidence is understood to provide valuable answers to the research question. Hence, determining the most appropriate approach is crucial to achieving a research goal.

The three main methodological approaches are the deductive, inductive and abductive approaches (Saunders *et al*., 2016). Malhotra (2017) describes the inductive approach from a bottom-up perspective, stating that it seeks to make limited generalisations about how observed or measured characteristics of people and social phenomena are associated. The author states that the deductive approach is the opposite of the inductive approach. This top-down approach begins explicitly with a tentative hypothesis or group of assumptions that create a theory that might give an answer or explanation for a particular situation and then test the hypotheses using data.

Abduction is using data to study phenomena, find themes, and explain patterns to generate a new or change an existing hypothesis, which is then tested, usually by collecting additional data (Saunders *et al*., 2016). Malhotra further points out that the abductive strategy can answer both ‘what‘ and ‘why‘ questions, whereas the inductive approach can only answer ‘what‘ questions, and the deductive approach can only answer ‘why‘ questions. Thus, an abductive approach leads to new insight into existing phenomena by examining these from a new perspective. Most importantly, the selection of a research approach should be based on the nature of the research problem or issue being addressed, the researchers’ personal experiences, and the audiences for the study (Creswell, 2014).

3.2.2.1. Justification of the Abductive Approach for this Study

Following Malhotra’s explanation of abduction in the previous section, it was assumed that an abductive approach was best suited for this study. This approach helped the researcher access the necessary information required to build the research and is best fitted for the study design. The abductive approach is described by Saunders *et al*. (2016) as combining the deductive (theory to data) and inductive (data to theory) approaches, or back and forth. Therefore, this research will leverage the benefits of both approaches while addressing any limitations. Furthermore, abduction is employed to transition from lay accounts of daily life to technical, scientific, or expert representations of that social life (Malhotra, 2017). Finally, abduction is frequently referred to as "Inference to the Best Explanation" (Douven, 2017) and is, therefore, best for the explanatory framework of this study.

3.2.3. Implementation of Mixed Method

After the research approach is the methodological choice, the third layer of the ‘Research Onion’ model by Saunders and his colleagues. The ‘onion’ reveals three primary methods: the mono method, multimethod, and mixed methods, which require quantitative (numerical data), qualitative (non-numerical data), and combined data collection techniques. As mentioned in the preceding sections, the complex nature of waste management research requires various methods for the inquiry. While the mono method involves the application of a single technique, either qualitative or quantitative, the multimethod requires a combination of two or more quantitative or qualitative techniques, depending on the nature of the research.

A mixed-method technique is defined as collecting, analysing, and mixing or integrating both quantitative and qualitative data within a single study at some stage of the research process to gain a better understanding of the research problem (Johnson *et al*., 2007, p. 123; Teddlie and Tashakkori, 2011, p. 285). While the quantitative method provides an objective measure of reality, the qualitative method allows the researcher to explore and better understand the complexity of a phenomenon (Williams, 2007). Johnson and Onwueguzie (2004) noted that both methods have limitations when applied individually. According to the authors, the information generated using quantitative methods may be too abstract and general to relate to local circumstances, contexts, and people directly.

In contrast, qualitative methods may have lower credibility when applied in research involving administrators and commissioners of programs. Stemming the limitations of these methods, the mixed-method approach has become more popular and recognized as the third central research approach. Johnson and Turner (2003) explain that the basic concept of mixed study allows a researcher to blend or merge methods by recognizing the strengths and limitations of quantitative and qualitative research.

Social phenomena are multi-dimensional and thus should not be studied along a single dimension alone (Mason, 2006; May, 2010). Therefore, a mono inquiry would not have suited this study based on its aim, questions, and scope, which required a rigorous approach to complex issues. Hence, the fundamental concept guiding the use of a mixed methods design in this study is that it incorporates a pragmatic worldview and combining many types of data sources yields a more comprehensive knowledge of a study subject than a single or monomethod approach (Guest & Fleming, 2014), hence the use of questionnaires and FGDs.

Furthermore, it sought to address research questions that cannot be answered by a single technique and incorporates the collaboration of those with knowledge in the field of inquiry. This study's primary inquiry began with a survey to explore the waste management challenges and assess public WM practises, guiding expert explanations in the qualitative phase. The practicality of this technique relies on the assumption that people often employ numbers and words to solve problems, thereby combining deductive and inductive logic through abductive reasoning (Morgan, 2007; Creswell & Plano Clark, 2018).

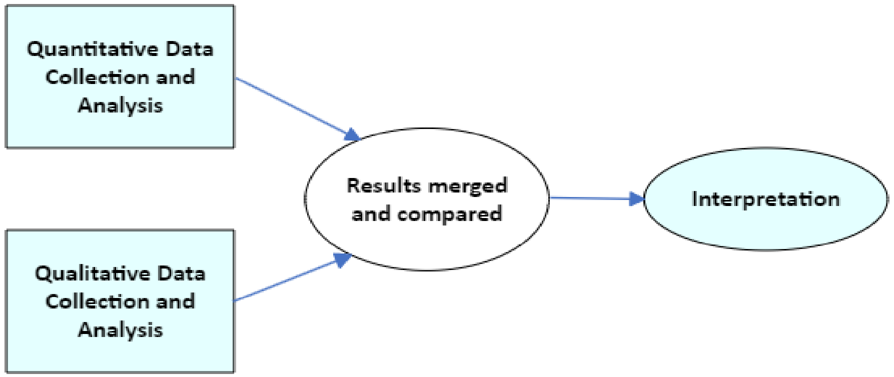
3.2.3.1. Types of Mixed Method Designs

The mixed method field has evolved over the years, leading to numerous classifications from various researchers. Teddlie and Tashakkori (2011) argue that the structure of mixed methods research can take varying forms and can be considered on a scale of weak to solid, depending on the degree of system integration, data collection, analysis, and performance. The authors explained that the data collection within this design may be sequential, where the components are conducted one after the other, or concurrent, where both components are conducted simultaneously and can be integrated into one or more stages of the research.

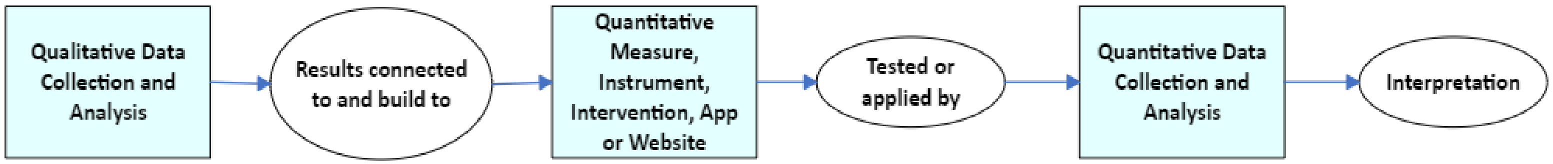
Creswell & Plano Clark (2018) extensively review the various types of mixed method designs from different authors in diverse disciplines based on the intent for mixing methods. These frameworks were based on either timing, weighting, or integrating qualitative and quantitative data. They then advanced three core types of designs: Explanatory Sequential, Exploratory Sequential and Convergent designs. They argue that the intent of a design is the expected outcome from mixing quantitative and qualitative data. Hence, a researcher intends to either converge, explore or explain. Using the mixed methods notation system developed by Morse (1991), Creswell and Plano Clark describe the three design frameworks illustrated in Figure 3.2. Morse's system uses shorthand and uppercase letters (QUAN, QUAL) to indicate the prioritised method and lowercase (quan, qual) to indicate the secondary method.

Furthermore, a plus sign (+) indicates that the methods run concurrently, while an arrow (→) indicates methods that occur in a sequence. The convergent design consists of a single study phase where quantitative and qualitative data are collected and analysed for comparison, or so they can be combined. In this design, both datasets are collected concurrently or within the same timeframe, distinguishing it from the exploratory and explanatory designs, which involve data collection sequentially. According to Creswell and Plano Clark (2018), the exploratory sequential design typically begins with and prioritises the collection and analysis of the qualitative phase, guiding the development of the second quantitative phase.

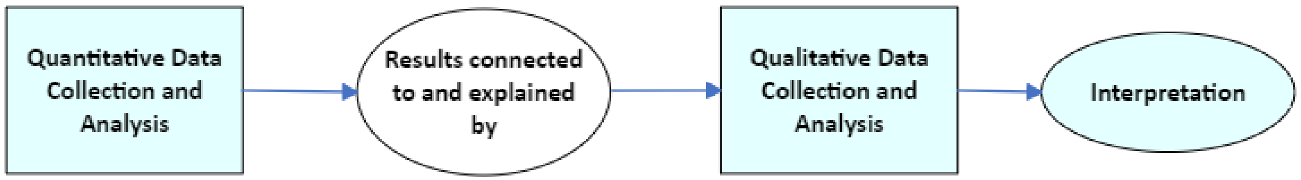
Figure 0.19 *Types of Mixed Method Designs*



The Convergent Design (QUAN + QUAL)



The Exploratory Sequential Design (QUAL → quan)



The Explanatory Sequential Design (QUAN → qual)

(*Note*: Adapted from Creswell and Plano Clark, 2018)

This study adopted the third core typology, the **explanatory sequential design**. This design consists of two distinct phases: quantitative and qualitative (Creswell, 2003). In this design, a researcher first collects and analyses the quantitative data. The qualitative data are collected and analysed second in the sequence to help explain or elaborate on the quantitative results obtained in the first phase. The second, qualitative, phase builds on the first, quantitative, phase, and the two phases are connected in the intermediate stage of the study. The explanatory sequential design may be lengthy and time-consuming (Creswell, 2009); however, the rationale for selecting this design is that the quantitative data and their subsequent analysis will provide a general understanding of the research problems, while the qualitative data and their analysis will refine and explain those statistical results by exploring participants' views in more depth (Teddlie and Tashakkori, 2011).

Driven by the advancement of environmental management and sustainability as a scholarly field which requires an understanding and application of various research methods, researchers are applying this method to their research designs. For example, Nuwematwsiko *et al*. (2021) employed an explanatory sequential design to investigate the knowledge, perceptions and practices of electronic waste management among consumers in Kampala, Uganda. Similarly, Ampofo (2020) used an explanatory sequential design to assess waste disposal management across various schools in Ghana.

In the context of this study, the design followed municipal solid waste, from the waste generators through quantitative methods to the collectors and the decision-makers through qualitative methods. In the first phase, a questionnaire survey was conducted within the study area, followed by a second phase of FGDs to understand and explain some of the results of the first phase; this helped the researcher explore waste management while understanding the views of the various stakeholders in Abuja. The following sub-section delves deeper into the "onion" and describes the research strategy adopted for this study.

3.2.4. A Case Study Strategy

A research strategy is a general plan that guides the researcher in selecting the primary data-collecting techniques or methods to answer the research question and achieve the research objectives (Melnicovas, 2018). According to Saunder's onion model, the research strategy layer succeeds the methodological choice layer. The author suggests that the primary research strategies are surveys, experiments, archival research, grounded theory, case studies, ethnography, action research, and narrative inquiry. Yin (2009) explains that the choice of which strategy to use in research can be determined by the nature of the research questions, the extent of control of the researcher over behavioural events, and the degree of focus on recent as opposed to historical events. However, Denscombe (2010) argues that no single research strategy can be recommended as the best in all circumstances.

For this research, a case study strategy was integrated within the explanatory sequential mixed methods. According to Saunders *et al*. (2012), the case study is the most utilised technique of enquiry in exploratory and explanatory research. The main reason for using this strategy is that, as Yin (2014) explained, case studies involve investigating one or more real-life issues to capture their complexity and details. Hence, it allows for an in-depth exploration of processes. Also, the researcher observed throughout the research and did not influence participant attitudes or waste arising in the composition study.

3.2.4.1. Study Location: Abuja Federal Capital City

As mentioned in the introduction to this research, there is much focus on Nigeria, primarily due to its rapidly expanding population, high urbanisation rate, and role in the rising waste quantities in Sub-Saharan Africa. Abuja is the modern capital city of Nigeria and the most rapidly growing city in Africa, with an urbanisation rate of 8.32% per annum (Myers, 2011). It is considered the first pre-planned city in Nigeria with a bid to reduce the burden of overcrowding and poor infrastructure in Lagos state, the previous capital. However, the rapid urbanisation rates and population growth suggest why the city's administrators struggle to provide basic public services (Abubakar, 2014). The primary considerations for choosing Abuja as the study area for this research were:

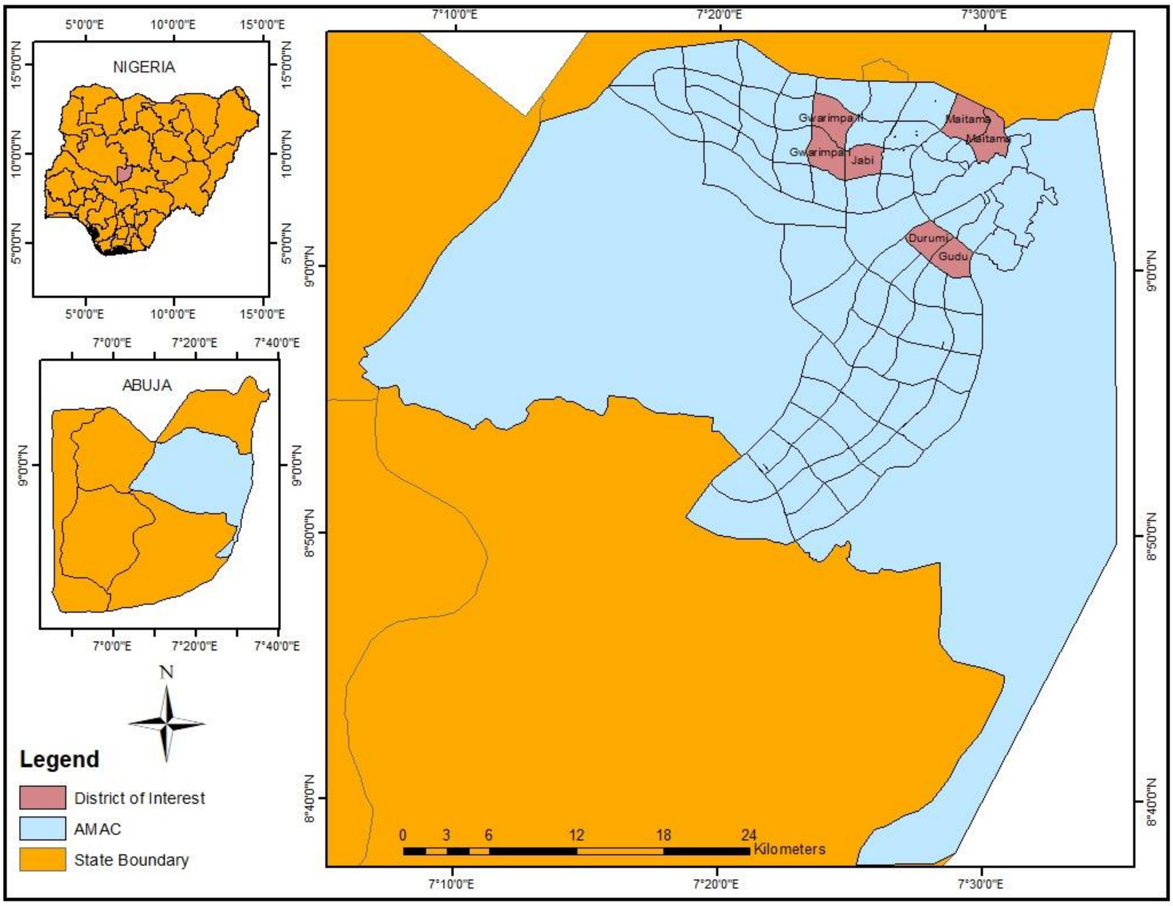
- Abuja is a federal capital territory within Nigeria, and a city within that territory serving as the nation's capital. It is the key location for all central government institutions and is home to significant stakeholders and decision-makers.

- It is Nigeria’s first pre-planned city and is primarily considered a model city.
- Abuja has one of the highest urbanisation rates in Africa, with a rapidly growing population, which translates to increasing waste generation.
- The city's high urbanisation rate presents a rich demographic mix of different cultures and social characteristics.
- Abuja has a functional waste management system; many private companies are operational in the city.

This study focuses on the Federal Capital City (FCC) within the Abuja Municipal Area Council (AMAC), one of the six Abuja area councils. AMAC is the biggest, most urbanised, and most developed of Abuja‘s area councils. It plays host to most public establishments in Abuja, and as Adama (2012) noted, the area has undergone spatial, economic, sociocultural, and political transformations.

The Federal Capital Territory Administration (FCTA), led by a minister selected by the president, is directly in charge of the city. The Abuja Water Board, the Abuja Environmental Protection Board, which oversees solid and liquid waste management, the Abuja Geographic Information System in charge of land administration, and the Transportation Secretariat are all part of the FCTA (Abubakar, 2014). The location is situated between the Equator‘s latitudes of 8°36‘ N and 9°21‘ N and the Greenwich Meridian‘s longitudes of 7°07‘ E and 7°33‘ E. It occupies around 1,500 sq km, or 38.8%, of the Federal Capital Territory‘s (FCT) total land area. Most of the area is rich in infrastructure, such as expanding road networks, drainage and sewage systems, and piped water, making it suitable and conducive to human habitation and settlement growth.

__Figure 0.20__ Map of FCT Abuja showing the Sampled districts



Nigeria's capital city, Abuja, has a moderate climate featuring savannah vegetation. According to the Koeppen climate classification, it falls under the tropical wet and dry climate category. The city experiences distinct rainy and dry seasons. Abuja‘s rainy season typically begins in April and lasts until October. During this period, daytime temperatures range from 28°C (82.4°F) to 30°C (86.0°F), while night-time temperatures hover around 22°C (71.6°F) to 23°C (73.4°F). Regular rainfall characterises the season, which aids in the growth of vegetation and sustains the savannah ecosystem (NiMET, 2020). On the other hand, Abuja‘s dry season is hot and dry. Daytime temperatures can soar as high as 40°C (104.0°F), while nighttime temperatures can drop to 12°C (53.6°F). Even during cold nights, daytime temperatures rise above 30°C (86.0°F). The dry season is associated with a scarcity of rainfall and lower humidity levels (Adams & Bamanga, 2020).

3.2.5. Research Time Horizon

A research time horizon specifies the time frame for carrying out a study. Saunders *et al*. (2019) identify two categories based on this, namely cross-sectional and longitudinal studies. A cross-sectional study investigates a topic over a certain period, and such research aims to present a snapshot of a continuous situation (Saunders *et al*., 2012). In contrast, a longitudinal research study is conducted over a lengthy period to observe and examine changes and developments (Saunders *et al*., 2012). Thus, researchers use longitudinal techniques to study phenomena that vary over time, such as developmental stages, intervention responses, and social trends. The time horizon for this study was established as **cross-sectional** for three reasons. Firstly, only a cross-section of the Abuja population was used for the study within a short timeframe. Another reason is that different groups within the population are compared in this study. The third reason is that statistical tests were used to determine the correlation between variables.

3.3. Research Methods and Data Collection

This section discusses the data collection procedures for both phases of the explanatory sequential mixed method design, study area and population, sampling methodologies, and methods employed for data analysis. Following an extensive literature review to provide a foundation of knowledge and arguments, the researcher applied qualitative and quantitative methods to synthesise evidence and understand Abuja's existing waste management system.

3.3.1. Quantitative Data Collection (Phase 1)

The first phase of data collection, the quantitative strand, consisted of two data collection sets: a questionnaire survey and a waste composition study. Details of how the sample was derived, the development and administration process of the survey instrument, and the waste composition analysis process are discussed in the following sections.

3.3.1.1. Quantitative Sampling Techniques

Sampling generally describes the selection of a subset of a larger population to gather information for a survey or investigation. Sharma (2017) defines sampling as a procedure used by a researcher to systematically select a relatively smaller number of representatives (a subset) from a pre-defined population to serve as subjects (data sources) for observation or experimentation following the objectives of his or her study. According to Fricker (2016), the idea is to draw a group from a population and use the data collected to infer information representing the entire population. Sharma (2017) argues that sampling procedures must consider essential factors. These include the study objectives, the population size and variance, its homogeneity and heterogeneity, the sampling techniques to be employed, and the accuracy level of inference about the population. Following the decision on Abuja as the study area for this research, it was necessary to decide on sampling techniques based on the abovementioned factors. The key consideration was to ensure an excellent socioeconomic representation of the population. There are two primary sampling techniques: probability sampling, in which the probability of choosing everyone is the same, and non-probability method, which is based on judgment (Alvi, 2016). Table 3.3 highlights the different types of probability and non-probability sampling techniques.

Table 0.8 *Probability and Non-Probability Sampling Techniques*

PROBABILITY TECHNIQUES	NON-PROBABILITY TECHNIQUES
Simple Random Sampling	Quota Sampling
Cluster Sampling	Purposive Sampling
Stratified Sampling	Self-Selection Sampling
Systematic Sampling	Snowball Sampling

(*Note*. From Alvi, 2016)

Stratified random sampling was the overarching technique employed for the quantitative phase of this study. This probability technique is most suitable for this kind of study as it ensures uniform coverage of the area under study (Edjabou *et al*., 2015). It involves the division of a population into smaller groups known as strata, followed by the random selection of participants from each stratum. The study area was divided into non-overlapping geographic sub-areas with similar characteristics while considering respondents' socioeconomic status. The standard of housing infrastructure and the presence of social and economic facilities were used as indices to determine the income levels of households within the districts, as shown in Table 3.4. This classification technique is widely accepted since decisions on service delivery, including waste management, are based on similar classifications (Miezah *et al*., 2015). Similarly, Adama (2012), in research on urban governance and spatial inequality in service delivery in Abuja, noted that infrastructure is a criterion used to estimate the charges for waste management services.

Table 0.9 *Districts, Income Levels and Accommodation Types*

DISTRICT	INCOME Classification	ACCOMMODATION TYPES
Maitama	High	Detached, Semi-detached
Jabi	Middle - High	Block of flats, Detached, Semi-detached
Gwarinpa	Middle	Block of flats
Durunmi	Low - Middle	Blocks of flats, Self-contained shacks
Gudu	Low	Self-contained, shacks

Table 3.4 shows the five districts sampled for the survey in Abuja Municipality to capture the range of existing socio-economic and demographic characteristics relevant to the study. These districts are part of the Federal Capital City (FCC), the most developed part of the municipality. The districts are Maitama, Jabi, Gwarinpa, Gudu and Durunmi districts. It was observed that the standard of housing infrastructure and the presence of social and economic facilities vary among the districts. Located north of the city, Maitama was created in Phase 1 of the original master plan of the Federal Capital Territory and designed to be among the best residential districts and the abodes of senior government officials. Like most high-income areas, Maitama has a low population density and is characterised by mansions and good road networks.

Jabi district, a development area in Phase 2 of the plan, is considered a middle-high-income area in the city and is mainly residential. Jabi has a total area of 486 hectares, of which 140 hectares are made up of natural features, including the centrally positioned Jabi Lake, rock outcrops, and streams. Kado District, Utako District, and Gwaripma District form the northern, eastern, and western boundaries of Jabi District.

Gwarinpa is the most populated district in the Abuja Municipal Area Council, located in Phase 3. It is located along the Kubwa-Suleja Expressway, about 20 kilometres from AMAC‘s central district. It has the most significant single housing development in Nigeria, an expansion and development primarily attributed to the growing rate of urbanisation in Abuja. Durumi and Gudu districts are part of the Phase 2 plan and share a border south of the Abuja Central Business district and towards the less developed outskirts of the city.

3.3.1.2. Survey Sample Size

Determining an appropriate sample size is a critical aspect of research methodology, ensuring that the collected data is representative of the population and allows for the generalisation of the findings (Sekaran & Bougie, 2010). In this study, the population of the Abuja FCC was estimated at 2,376,500 (JICA, 2019; NBS, 2019). Due to the unavailability of a breakdown of population distribution among the districts within AMAC, the researchers assumed that a sample size of 400 would be suitable for the survey study. This sample size falls within the range suggested for sample size calculations by Meyer (1979), Fox et al. (2007), and Oribhabor and Anyanwu (2019) for similar populations.

3.3.1.3. Questionnaire Design

A questionnaire can be described as a quantitative research tool that provides essential information that is adequate for interpretation (de Vaus, 2013). Questionnaires aim to provide researchers with an objective means of collecting information about people’s beliefs, knowledge, attitudes, and behaviour. They are considered valid if it is easy for participants to answer correctly (Jain et al., 2016). Following this recommendation, the questionnaire was constructed as clear, simple, specific and relevant to the study’s research questions. Revisiting the research questions and reviewing past literature were critical to the questionnaire development. The research problem guided the construction of the concepts that needed to be measured and were crucial in determining which questions needed to be asked.

Due to the available data collection and analysis time, closed-ended and open-ended questions were used as the survey instrument. Lavarakas (2008) describes a closed-ended survey question as providing respondents with a fixed number of responses from which to choose an answer in the form of a question stem and a set of answer choices. On the other hand, Pallant (2013) states that open-ended questions give the respondent no options to choose from and that the respondent is not restricted to specific options but is allowed to provide answers freely. The author also noted that although close-ended formats restrict the respondents' opinions, a significant advantage is that close-ended questions' response rate is usually high as they are easily understood and completed. Thus, the format was designed to capture the respondents' attention and generate accurate and reliable data while accommodating the large sample size. The questionnaire was divided into sections to elicit information on WM challenges and public participation. Nominal and ordinal scale questions were used in the questionnaire. These included multiple-choice and five-point Likert scale questions, which social science researchers have extensively used in various studies to collect participants' views, beliefs and attitudes towards a specific topic (Saunders, 2016).

3.3.1.4. Social Desirability Bias

When conducting environmental investigations, social norms play a significant role in determining what is considered right and wrong; this can lead to respondents who are influenced by these norms feeling compelled to provide biased answers. Survey questions which investigate behaviours that are not socially desirable often generate inaccurate result estimates (Krumpal, 2011). Thus, behaviours and attitudes which are socially desirable (e.g., willingness to pay for service) are over-reported, while socially undesirable behaviours (e.g. open dumping) are under-reported (Bradburn *et al*., 2004; Krumpal, 2011; de Vaus, 2014). Although the issue of social desirability is most significant when questionnaires are administered face-to-face, de Vaus (2014) points out that the problem still exists in online surveys.

The issues involved in waste management investigations can be deemed sensitive since they may involve respondent attitudes that are generally socially undesirable. For example, many people may not admit to practising open dumping due to the negative feeling of shame or the fear of the questionnaire being traced to them and getting fined or sanctioned. Hence, even in studies where the questions are not sensitive, or anonymity is assured, respondents focus on the sensitivity of their answers (Krumpal, 2011).

To reduce the effect of social desirability bias in this research, the techniques recommended by Fisher (1993) were followed. Fisher postulated that indirect questioning mitigates social desirability bias and does not systematically affect the means of variables independent of social influence. Fisher and Tellis (1998) point out that indirect questioning better represents respondents' underlying valid scores than direct questioning for socially sensitive variables. Therefore, indirect question types were used and followed by a question to build an excuse for the actions or behaviour. A copy can be seen in the questionnaire in Appendix C, where the respondents were asked indirectly about open dumping, followed by a question that gives an excuse for such behaviour.

3.3.1.5. Pilot Testing

Once the questionnaire had been developed, it was necessary to rigorously evaluate each question and the entire questionnaire, as de Vaus (2014) recommended. A pilot study was carried out, which is the pre-testing or ‘trying out’ of a particular research instrument (Baker, 1994) using a small group of participants in relation to the main sample size but similar to the primary target population. Lowe (2019) refers to a pilot study as a small feasibility study aimed at avoiding a fatal flaw that can be costly in time and money. These definitions highlight the importance of pilot studies before the main study.

Furthermore, Van Teijlingen and Hundley (2001) note that one of the advantages of conducting a pilot study is that it might give a warning about where the primary research project could fail, where research protocols may not be followed, or whether proposed methods or instruments are inappropriate or too complicated. However, as was the case in this research, Van Teijlingen and his colleague also noted that a significant disadvantage is the associated costs. Travelling to Nigeria to pre-test the questionnaires within the local setting would have been costly. Additionally, there were travel restrictions due to the COVID-19 pandemic during the planned period for data collection.

For these reasons, the Nigerian Students Association of the University of Salford (NSS), which consists mainly of students who reside in Nigeria, was used for the pilot survey. At the time of the survey, the NSS had 252 members on its WhatsApp group, and 78 had Abuja registered as their permanent residence in the database. The questionnaires were also sent by the same means to environmental professionals in Nigeria currently serving in the public sector. The aim was to evaluate the flow, question skips, timing and respondents' interest and flow, as de Vaus (2014) recommended.

The questionnaire draft was developed in Microsoft Word format and posted on the association's WhatsApp group for respondents who met the criteria (Abuja residents) to download, fill, and return via the same medium. Thirty-eight responses were returned, accounting for a response rate of 48 % of the 78 Abuja residents in the NSS. Vague questions were removed or lengthened to reduce the completion period and encourage participation. After that, the questionnaires were posted again to the group, and there was a significant increase in the response rate (75%). The feedback from the respondents was used to enhance the validity of the questionnaire. When addressing the research questions, the researcher's supervisor reviewed the final draft for clarity and validation.

3.3.1.6. Questionnaire Administration

Due to travel restrictions and other risks presented by the COVID-19 pandemic, adjustments had to be made to the study methodology. One significant change was the method of the survey administration. Given an extensive risk assessment, the researcher resorted to conducting the survey online, which was against the initially planned face-to-face distribution method. Online surveys involve the distribution of surveys via various electronic means, a method which has proliferated over the past decade (Tanner,2018). A significant advantage is that participants can rapidly deploy and complete it, primarily when disseminated via emails and social media platforms (Ball,2019). However, Ponto (2015) argues that although increasingly popular, a significant drawback is a high potential for bias when using online surveys. Another limitation acknowledged by Tanner is that internet access for participants to view and complete the questionnaire may not be available for many, as is the case in developing countries.

The developed questionnaire (see Appendix C) was uploaded to the Jisc online survey platform. The platform has the necessary tools and was developed mainly for university research. A preceding message stating that participation was only open to those residing in the districts chosen for the study was included in the questionnaire. The link to the survey was generated and shared with prospective respondents via email, WhatsApp, and LinkedIn. WhatsApp groups, such as church and market association groups, played a significant role in capturing different population classes. The survey was open between January and March 2021.

Contact was also made with AEPB and the National Environmental Standards and Regulations Enforcement Agency (NESREA) to help distribute the questionnaire through their research database. Three hundred fifty-five responses were collected at the end of the data collection period, providing a response rate of 85.8%. However, only 343 were valid. The simplicity of the questionnaire design can explain the high response rate, the modes of distribution, and the duration of data collection. The survey output guided the FGDs with experts in the waste management sector. Driscoll et al. (2007) noted that this form of sequential data collection using mixed methods is suitable for environmental researchers as it can provide critical insights into unexpected relationships between local resource use patterns and community factors.

3.3.1.7. Waste Composition Study

Investigating MSW composition is critical for assessing recovery potential and GHG emissions and developing future waste sorting, transportation, and treatment methods (Zhang *et al*., 2021). Waste streams are generally classified as organic and inorganic (Kaza *et al*., 2018), and although attempts have been made to standardise waste analysis methodologies, these have not been met with much success, and no agreed international standard defines the process (Defra, 2009). This research adopted the simple direct waste sampling method, which involved sorting and weighing individual categories of waste (Bandara *et al*., 2007). This method is similar to the primary approach taken in the United Kingdom for kerbside waste composition studies, which is to stratify the sample and then identify street blocks with characteristics that relate to a chosen stratum of the population of households to be sampled (Defra, 2009). The objective of the composition study was to explore waste generation and composition trends in Abuja.

3.3.1.7.1. Trial Composition Study

To test the proposed methods for the composition analysis, a waste audit was carried out within the premises of the University of Salford in collaboration with the University Sustainability team. The exercise was carried out at the waste compound on University Road in September 2019. The process helped the researcher prepare and adjust for further possibilities of errors that can occur during sampling. For example, it was observed during the process that a traditional floor scale would be preferable to a handheld scale for weighing samples. The trial results contributed to waste collection planning and emphasised the need for sensitisation on the university campus.

3.3.1.7.2. Primary Composition Study

The main composition study for this research took place in Abuja in October 2021. The objective of the fieldwork was to explore waste generation and composition trends in Abuja. The specific aim was to address questions related to waste generation and composition in Abuja, relating to the current quantities of different waste materials, variations in waste composition among different socioeconomic groups, and the impact of income levels on waste generation and composition. Before commencement, a study protocol was developed to cover the processes of the composition study; this included the following:

1. Recruitment and training of volunteers: Three volunteers, all students of the University of Abuja, were recruited and trained throughout the process.

2. Preparation of receiving site for waste samples: The Abuja Environmental Protection Board (AEPB), in collaboration with the Abuja Market Management Limited (AMML), provided covered storage space in the Gudu market facility. The site was visited, and its suitability was assessed.

3. Categorisation of waste material: The waste material was classified into ten categories (see Table 3.5) adapted from a similar categorisation by Hoornweg and Bhada-Tata (2012).

Table 0.10 *Waste data entry sheet sample*

	Waste Material	Components	Weight (kg)
1	Paper	Paper, cardboards	
2	PET	Plastic bottles	
3	Plastic Film	Plastic bags, plastic sachets	
4	Metal	Rods, springs, bolts etc	
5	Glass	Glass bottles, glass louvres, etc	
6	Food/Organic matter	Kitchen waste, biodegradables	
7	Textile	Fabrics	
8	Wood	Furniture cuttings etc	
9	Leather	Leather fabrics etc	
10	Others	Ash, highly contaminated waste (diapers), hazardous, WEE fragments, waste etc	

(*Note*. Adapted from Hoornweg & Bhada-Tata, 2016)

An even number of households were randomly selected for door-to-door sampling within each stratum, which formed a representative of the area. According to Parfitt, Griffiths, and Reid (2013), this method of waste sampling provides greater certainty about the waste‘s origin compared to methods that directly sample from collection vehicles or transfer stations. These alternative methods can potentially introduce biases into the sampling process. Due to the available time for the composition study, only three of the five districts, Gudu, Gwarinpa and Maitama districts, were sampled. Based on the dominant building characteristics in the area, the districts translate to low-income, middle-income, and high-income areas (see Table 3.4), relating to an even representation of each socioeconomic group. One key benefit of this approach is that using stratification means fewer samples are needed, as waste tends to vary less within each stratum than the entire population (Mizeah *et al*., 2015). Therefore, stratification improves the accuracy of composition estimations obtained for the same research resource (Parfitt *et al*., 2013). For this composition study, 24 houses (8 from each district) were sampled over five days. Houses on different streets within the districts were selected to improve the randomness. Visual observations of the buildings were used to validate the socioeconomic classification. Details on the number of occupants in each household were requested and noted. Samples from each household were collected and labelled in black bin bags, sealed to prevent mixing during transportation, marked with colour-coded ribbons for identification (according to locations), and then moved to a sorting facility where they were sorted and weighed to determine the overall mass, and characterised into the predesigned template in Table 3.5. The research team manually sorted it. In this study, ‘paper’ included paper and cardboard sheets (packaging), while ‘plastic film’ refers to plastic shopping bags and the popular sachet water packaging. ‘Others’ refers to any waste not under any categories, including ash, fragments of WEE and highly contaminated waste fractions. Equation 1 below was used to calculate the percentage composition of segregated waste components.

The most practical way to determine the generation of solid waste with any degree of reliability is to perform a materials balance analysis for each generation source, such as individual home or commercial activity (Tchobanoglous & Kreith, 2002). Thus, a materials balance analysis was used to determine the per capita generation for this research using the formula in Equation 2. The documented outcomes were then presented and analysed using descriptive statistics. The sample analysis process was conducted within 24 hours to avoid contamination and reduce likely errors.

$$\frac{Weight\ of\ the\ separated\ waste\ fraction}{Total\ weight\ of\ the\ bag} \times 100$$

Equation 1: Percentage composition of waste fraction (Miezah *et al*., 2015)

$$\frac{Weight\ of\ waste\ generated\ at\ the\ household}{Number\ of\ persons\ in\ the\ household} \times Number\ of\ \ generation\ days$$

Equation 2: Per capita waste generation (Miezah *et al*., 2015)

3.3.1.8. Quantitative Data Analysis

Albers (2017) describes quantitative data analysis as a multistep iterative process that uses statistical tests as a tool for data interpretation. The data generated from the quantitative study was analysed using IBM SPSS Statistic version 27. The steps the researcher took to prepare the data for analysis and ensure its integrity are described in the following sections.

3.3.1.8.1. Data Screening and Normality

The first step of the analysis process involved data screening; this was essential in dealing with missing data and making an informed decision on the statistical application for the analysis. After the time given for participants to fill out the survey had elapsed, the responses were exported for the Jisc platform to Microsoft Excel, where the frequencies for each variable were checked, incomplete questionnaires were removed, and total scales were calculated before being subjected to further analysis.

The next component of the screening process was to check for the normality of distribution. Normality is the most important continuous probability distribution and has a bell-shaped density curve described by its mean and SD. According to researchers (Ghasemi & Zahediasl, 2012; Narwaria et al., 2018; Uttley, 2019), assessing the normality assumption should be considered before deciding on parametric or non-parametric statistical tests. Given this, normality tests were carried out for both strands of the quantitative study (Survey and waste composition).

Two standard methods of assessing normality are the visual inspection of the distribution and a numerical test. Both methods were applied for the normality test in this research. Hence, where graphical interpretations were unclear, the researcher relied on numeric statistical tests using SPSS. Statistical tests were done using two of the most common test methods (Mishra et al., 2019), Shapiro–Wilk and Kolmogorov–Smirnov tests. Examples of the normality tests of the variables in the questionnaire survey and the waste composition study can be seen in Tables 3.6 and 3.7, respectively.

Table 0.11 *Normality Test Results for Sociodemographic Variables*

Tests of Normality						
	Kolmogorov-Smirnova			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
What is your gender?	0.314	343	<.001	0.723	343	<.001
Which of the following categories includes your age?	0.234	343	<.001	0.836	343	<.001
What is your level of education?	0.315	343	<.001	0.822	343	<.001

What is your occupation?	0.215	343	<.001	0.885	343	<.001
What is your religion?	0.363	343	<.001	0.657	343	<.001
Which district in Abuja do you reside in?	0.253	343	<.001	0.868	343	<.001
What is your household size?	0.231	343	<.001	0.879	343	<.001
a Lilliefors Significance Correction						

Some authors (Ghasemi & Zahediasl, 2012; Mishra et al., 2019) argue that for small sample sizes (< 50), the Shapiro–Wilk test is more appropriate, while the Kolmogorov-Smirnov test should be used for larger sample sizes (> 50). Therefore, based on the sample size of the survey in this study (n = 343), the emphasis was on the Kolmogorov-Smirnov test for interpretation. The null hypothesis (H_0) for the Kolmogorov–Smirnov tests assumes that the data follows a normal distribution if the p-value is greater than 0.05 ($p > .05$). An extract of the normality test of the survey data in Table 3.6 shows significant values for all categories as the p-values are all less than 0.05. Hence, the null hypothesis was rejected, and it was assumed that the data did not come from a normal distribution. The normality test of the waste samples showed non-normal and normal distributions among the sampled districts, as shown in Table 3.7; this may be due to the heterogeneous nature of waste samples.

Table 0.12 *Normality Test Results for Waste Composition Components*

Tests of Normality							
	District	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Paper	Maitama	.107	40	.200*	.953	40	.099
	Gwarinpa	.113	40	.200*	.934	40	.021
	Gudu	.098	40	.200*	.960	40	.171
PET	Maitama	.088	40	.200*	.960	40	.168
	Gwarinpa	.111	40	.200*	.916	40	.006
	Gudu	.182	40	.002	.919	40	.007
Plastic Film	Maitama	.153	40	.019	.925	40	.011
	Gwarinpa	.096	40	.200*	.958	40	.147
	Gudu	.080	40	.200*	.965	40	.254
Metal	Maitama	.228	40	.000	.856	40	.000
	Gwarinpa	.147	40	.029	.898	40	.002
	Gudu	.129	40	.092	.945	40	.053
Glass	Maitama	.151	40	.022	.926	40	.012
	Gwarinpa	.152	40	.021	.963	40	.209
	Gudu	.194	40	.001	.902	40	.002
Food	Maitama	.086	40	.200*	.962	40	.193
	Gwarinpa	.164	40	.008	.921	40	.008
	Gudu	.166	40	.007	.907	40	.003

Textile	Maitama	.125	40	.120	.935	40	.024
	Gwarinpa	.126	40	.109	.949	40	.068
	Gudu	.233	40	.000	.852	40	.000
Wood	Maitama	.105	40	.200*	.945	40	.051
	Gwarinpa	.115	40	.200*	.958	40	.147
	Gudu	.098	40	.200*	.955	40	.116
Leather	Maitama	.154	40	.018	.931	40	.018
	Gwarinpa	.145	40	.033	.915	40	.005
	Gudu	.466	40	.000	.539	40	.000
Others/contaminated	Maitama	.116	40	.193	.943	40	.044
	Gwarinpa	.107	40	.200*	.962	40	.199
	Gudu	.070	40	.200*	.958	40	.142
*. This is a lower bound of the true significance.							
a. Lilliefors Significance Correction							

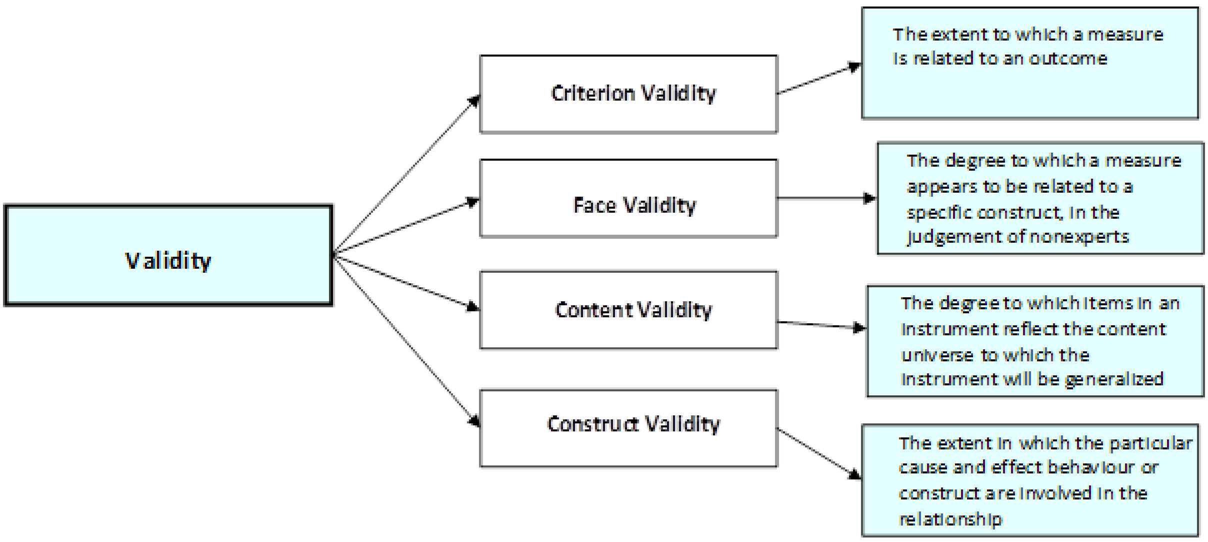
For example, within the Maitama district, the Kolmogorov-Smirnov test results for paper, PET, wood and food components indicated concordance to normality ($p > .05$). At the same time, glass, plastic film and metal showed evidence against normality ($p < .05$). However, the null hypothesis was rejected since it required all waste components follow a normal distribution if the p-value is more significant than 0.05. Following the outcome of the normality tests of the quantitative data, Ghasemi and Zahediasl (2012) argue that in such cases, it is required that the non-normal variables are transformed, or a non-parametric test is used for analysis. However, Pallant (2020) disagrees by stating that based on the Central Limit Theorem, with large enough sample sizes (> 30), the violation of the normality assumption, as observed in this study, should not cause significant problems. Sainani (2012) believes the theory is applicable with a sample size of at least 80. Drawing from Elliot and Woodward (2007), Ghasemi and Zahediasl (2012) later acknowledge that parametric procedures can still be applied in cases where normality is not met. However, Mishra et al. (2019) recommend that the assumption of normality should be followed irrespective of the sample size for meaningful conclusions. With these arguments in mind, the decision on the statistical method of choice in this research was made with consideration of meeting other assumptions.

3.3.1.8.2. Validity and Reliability of the Research Instrument

For the findings of this research to achieve empirical and scientific standing, it was essential to ensure the instrument was well-calibrated. Validity and Reliability are critical to examining and maintaining the quality of quantitative data collection methods and tools. Validity covers how effectively the data collection methods cover the scope of the investigation (Ghauri & Gronhaug, 2020). In other words, does the instrument measure what it intended to measure? Singh (2017) states that the validity of a study relies on the degree of systematic error. According to Taherdoost (2017), the four significant types of validity are face, content, construct, and criterion. These are further explained in Figure 3.4. Taherdoost, in his exploration of validity, maintains that it is often confusing for researchers to determine how validity tests apply to their research. For this study, content, construct, and face validity were established based on the following measures.

1. The questionnaire development was guided by reviewed literature
2. A pilot study was conducted, and a channel to receive valuable feedback was used to improve the readability and enhance the quality of the research tool
3. Input from experts in the research field was used to refine the questions and ensure the purpose of each statement was appropriate for the questionnaire.
4. Multiple data collection methods provided evidence and maintained consistency throughout the analysis.

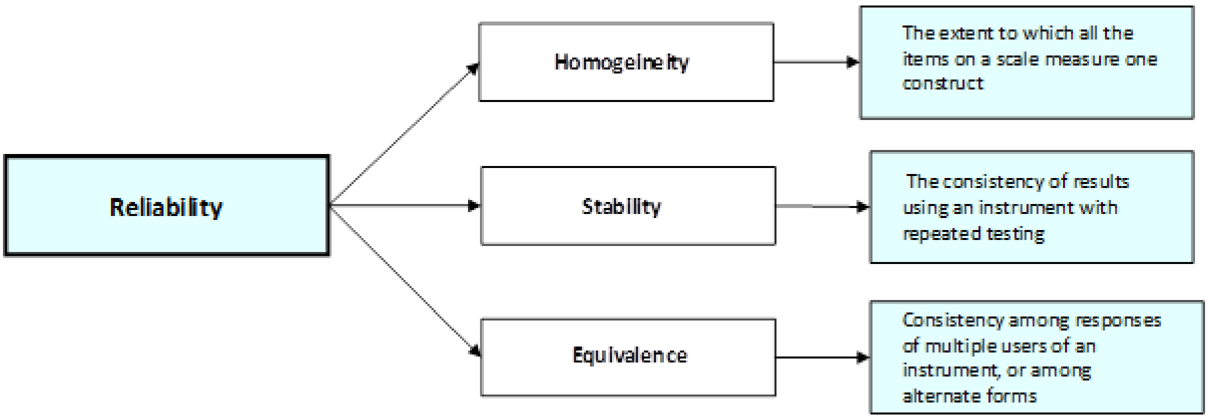
Figure 0.21 *Types of Validity*



(*Note*: Adapted from Taherdoost 2017)

Testing for reliability is essential as it refers to the consistency across the parts of a measuring instrument (Huck, 2007; Taherdoost, 2017). Hence, a reliable tool is expected to produce similar results when applied simultaneously. Though unlikely due to factors that might affect the population sample over time, a strong positive relationship between the measuring instrument's results makes a case for its reliability (Sürücü & Maslakçi, 2020). Heale and Twycross (2015) propose three main reliability attributes (Figure 3.5). These are homogeneity, stability, and equivalence, which are tested through different measures. However, the authors argue that it is impossible to give an exact reliability calculation and that only an estimate can be achieved. In literature, most researchers test for homogeneity by checking the reliability of scales, and the most widely accepted test method is the alpha coefficient, specifically Cronbach's alpha (Sürücü & Maslakçi, 2020).

Figure 0.22 *Reliability Attributes*



(*Note*: adapted from Healyand Twycros, 2015)

For this study, Cronbach's alpha test was used to determine the internal consistency of the survey by testing the scale questions. Internal consistency is strong when Cronbach's alpha coefficient, which has a value between 0 and 1, approaches +1 (Pallant, 2016). According to DeVellis (2012), the ideal alpha coefficient of a scale should be above .7. Using SPSS, the reliability test conducted on the questionnaire in this research resulted in coefficients of 0.797 and 0.721, which, according to Pallant (2016), shows a good level of internal consistency. Table 3.8 shows Cronbach's result of the scales in the questionnaire.

Table 0.13 *Cronbach's Test Results*

Reliability Statistics		
Construct	**No of Items**	**Cronbach's Alpha**
MAwareness	5	.797

MSatisfaction	5	.721

3.3.1.8.3. Descriptive Statistics

After ensuring no errors were in the data file, a preliminary analysis phase was used to inspect the data and explore variables. The goal was to condense the raw data into a more straightforward summary and lay the foundation for inferential analysis. May (2011, p.122) notes that researchers can conduct validity checks on their samples by utilising descriptive analysis and identifying central tendency and dispersion. IBM SPSS Statistic 27 was used to analyse Section A of the questionnaire, which focused on the participants' demographic profiles. This descriptive analysis encompassed a comprehensive examination of key demographic attributes such as gender distribution, education levels, ages, residential districts, and other pertinent background information essential for conducting meaningful analyses. Visual aids like pie charts, bar graphs, and tables were employed when necessary to facilitate the exploration of these facets. Through these techniques, the researcher understood the nominal, ordinal, and dichotomous variables within the dataset, which proved invaluable for subsequent analysis.

3.3.1.8.4. Inferential Statistics

Building on the insights derived from the descriptive analysis, the study progressed to the phase of inferential analysis. The primary objective was to ascertain whether the observed patterns identified within the sample were generalisable to the broader population (de Vaus, 2014). Pallant (2016) suggests that correlation techniques are suitable when the researcher lacks direct manipulation of independent variables and works with naturally occurring variables. Using inferential statistics, particularly correlation techniques, facilitated exploring relationships between variables. By doing so, the study aimed to conclude the potential alignment of these relationships with the broader population. This analysis phase involved a deeper investigation into the interplay of variables and contributed to a more nuanced understanding of the research context.

3.3.2. Qualitative Data Collection (Phase 2)

A qualitative approach was employed in the second phase of the research design to provide more detail and rich data for understanding the phenomenon under investigation. After the quantitative analysis, the researcher identified the quantitative results for further explanations and who could best provide the explanations. Hence, the results were used to develop the focus group agenda. The qualitative phase's data collection and analysis procedures are described in the following sections.

3.3.2.1. Qualitative Sampling Techniques

To gain quality data and purposeful insight into specific findings from the quantitative analysis**, purposive sampling** was adopted for the qualitative phase of the research (FGDs). Purposive sampling is a type of non-probability sampling that is most effective when one needs to study a particular cultural domain with experts (Tongco, 2007). A significant challenge in the explanatory sequential design is connecting both design phases at the sampling stage (Morgan, 2013; Pallant, 2016). When applying the explanatory sequential design, various researchers recruit a qualitative sample from respondents in the quantitative phase; this is in line with the recommendations of Pallant (2013) that for explanatory designs, participants in the qualitative phase should be drawn from the quantitative phase. However, this is not always feasible where expert opinions are required or the researcher cannot access participants for the follow-up qualitative phase.

Morgan (2013) addresses this issue by arguing that the purpose of an explanatory sequential design is to improve the understanding of the quantitative results; hence, a new sample can be drawn to explain and understand. These views are adopted for the explanatory design of this study. The pragmatic approach to the research sequential framework followed MSW from the point of generation by first exploring the current situation through quantitative techniques and then expanding on the findings through qualitative techniques. Therefore, the views of various WM stakeholders were examined to achieve the aim. Hence, participants in the qualitative phase were experts drawn from the waste management sector with direct experience in dealing with waste issues on the ground. The purposive sampling technique was applied to the qualitative phase and is discussed in detail within the sections describing both research methods.

3.3.2.2. Focus Group Discussions (FGDs)

A focus group is defined by Longhurst (2003) as a group of people, usually between six and twelve, who meet in an informal setting to discuss a topic set by a researcher, allowing the group to explore the subject from as many angles as they desire. Morgan (1998) states that the primary purpose of a FGD is to obtain in-depth information relating to concepts, perceptions, and practices in the context of the subject from group members. FGDs generally provide an excellent opportunity to gather preliminary information about a topic (Longhurst, 2003). Various researchers (Balch & Mertens, 1999; Mbeng, 2009; Yuan,2013) in similar environmental studies have successfully utilised FGDs to gain insight into the subject.

Online focus groups are gaining popularity as an alternative to traditional face-to-face meetings. They allow researchers to overcome challenges related to cost, location, and participant accessibility. (Zwaanswijk & van Dulmen, 2014). Stewart and Shamdasani (2017) argue that the advent of the Internet and networked communications have resulted in the proliferation of new social spaces devoid of physicality, thus increasing online data-gathering strategies. The authors propose that a significant advantage of online meetings is that participants can be more open than in traditional forms due to anonymity, the "informal" nature of online formats, the comfort of being in a familiar setting, and the influence of virtual group support.

Menary *et al*. (2021) posited that adapting to run focus groups online can be done without compromising research output quality. It provides a valuable alternative to in-person data collection in crises such as COVID-19. However, Stewart and Shamdasani maintained that a major criticism is an inability to reach traditional populations in low-income areas due to internet availability. Despite this criticism, the researcher resorted to online methods to reduce costs and assumed prospective purposively sampled participants would have internet access.

Consequently, with the objective in mind, participants in the FGDs were selected from industry experts involved in waste operations, particularly collection and disposal; this follows the recommendations of Saunders *et al*. (2019), who argue that participants should be selected based on common characteristics related to the research topic. Therefore, the researcher assumed that individuals with practical knowledge of waste management would be best suited to expand and create an understanding of the issues and significant findings from the quantitative phase.

3.3.2.2.1. FGD Recruitment and Agenda

The recruitment process involved sending formal invitations via email and phone messages to prospective participants, including staff of AEPB, the Federal Ministry of Environment, private waste management agents, and representatives of informal waste pickers. The invitations contained information on the purpose of the study and highlighted why they were invited to participate. In total, 20 invitations were sent out, and 12 participants indicated their availability to participate in the discussion. Subsequently, the participants were randomly split into two groups, and two independent meetings were scheduled on Zoom based on participant availability. The Zoom online platform was preferred as the online conferencing tool since most participants were familiar with it. One of the participants was excused during the second meeting due to technical issues. The participant profiles and groups for the meetings are detailed in Table 3.10.

Table 0.14 *FGD Participants Profiles*

FGD 1			
Sector	**Organisation**	**Position**	**Years of Experience**
Public	AEPB	Land Resource Officer	9
	AEPB	Supervisor	7
	AEPB	Supervisor	7
	AMAC	SCI Officer II	5
Private	Contractor	Head Operations	8
	Contractor	Supervisor II	5
FGD 2			
Public	AEPB	Supervisor	7
	Federal Ministry of Environment	Supervisor	8
Private	Contractor	Team Leader	7
	Contractor	Supervisor I	6
	Contractor	Operations/Driver	7

The researcher designed a semi-structured focus group agenda to guide the synchronous group discussions (Appendix E). The questions guiding the discussion were based on relevant findings from the quantitative study. The FGDs were held in

January 2022. For both meetings, it was necessary to create a semi-formal atmosphere to encourage the participants to discuss freely; this was achieved by the facilitator (the researcher) initiating general topics on the state of affairs in Nigeria, bringing about brief discussions on politics and the economy. Such ice-breaking activities can be creative and allow the members to share their views and create rapport (Lathen & Laestadius, 2021). The ice-breaking chat allowed some time for participants who were late to join, followed by revisiting the issue of consent, general housekeeping, introductions, and a general overview of the meeting order. The participants were also assured anonymity before obtaining permission to record the proceedings. The semi-formal atmosphere of the FGDs allowed participants to air their views freely on WM issues. Subsequently, the recordings from both meetings were transcribed verbatim and synthesised to generate helpful insight into WM in Abuja.

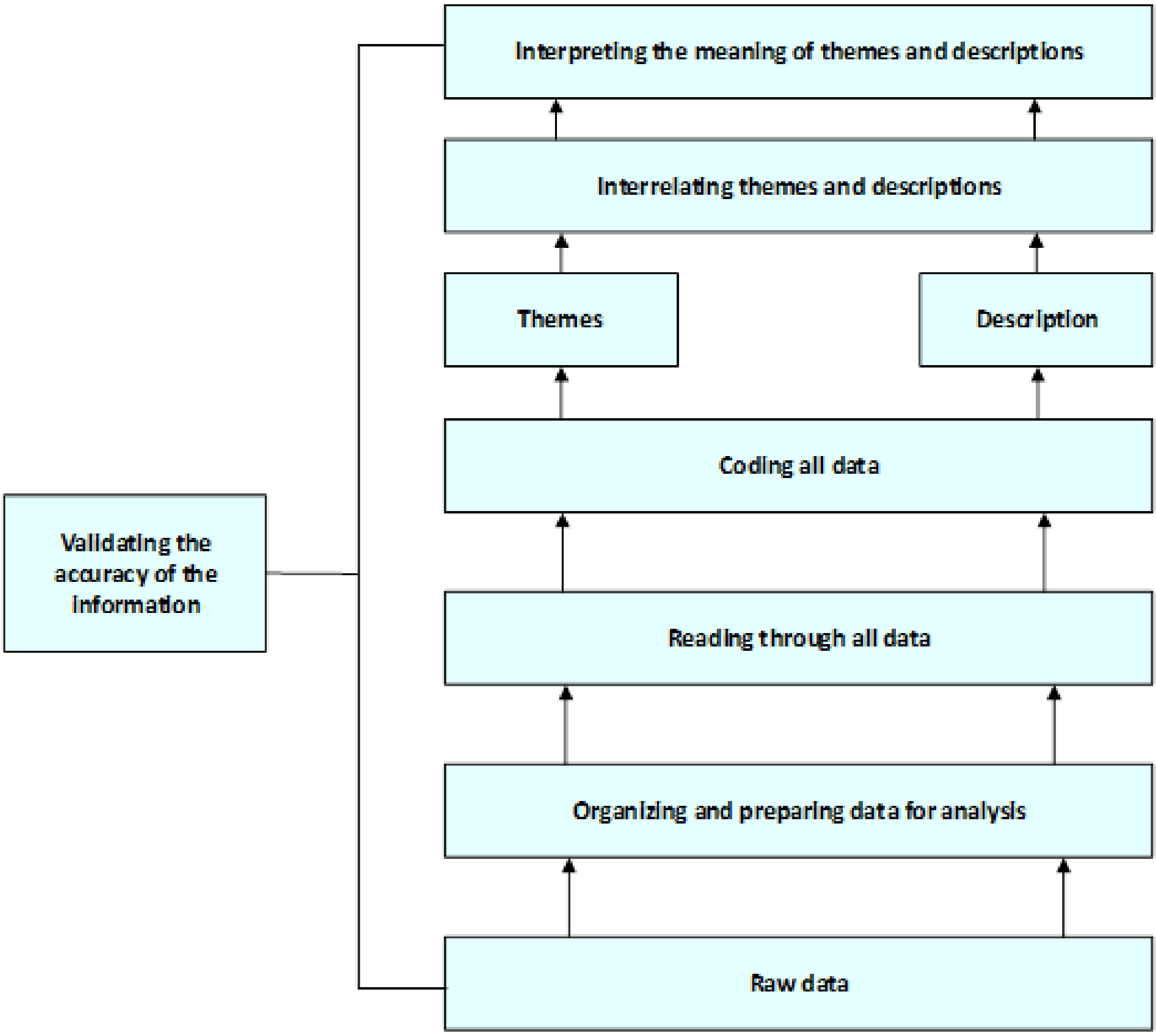
3.3.2.3. Qualitative Data Analysis

The consolidated stages of qualitative data analysis described by Creswell (2009) were adopted for the analysis in this study. The first step in analysing both components of the qualitative data was transcribing the data to enable readability. This critical step in the analysis process was carefully done to ensure the data validity was not compromised. After that, open coding was used for a line-by-line assessment of the transcribed data. Both preparatory techniques gave a deeper understanding of the data by highlighting salient comments and organising the data for analysis using the NVivo software. NVivo is a qualitative analysis software that helps discover themes, organisation, pattern identification, and qualitative data analysis (Bazeley, 2009).

The different epistemological perspectives and theoretical frameworks influence how the researcher approaches the data when it is time for analysis (Guest *et al*., 2011). This study employed a thematic analysis using deductive and inductive approaches to identify, analyse, and interpret themes within the qualitative data. By combining extant theoretical influence with raw data, the deductive and inductive approach to the data analysis ensured that the findings were grounded in existing knowledge while allowing for empirical discovery (Thompson, 2022).

Thematic analysis is defined by Braun and Clarke (2006, p. 79) as an independent qualitative descriptive approach that is mainly described as “a method for identifying, analysing and reporting patterns (themes) within data" (Vaismoradi *et al*., 2013). The researcher employed this method of analysis because of its ability to analyse small and large datasets and its theoretical flexibility (Clarke *et al*., 2015), which applies to the pragmatic underpinning of this research study. Bryman (2012) points out that this research method can be used in a wide range of studies, making it a versatile tool for researchers. However, one of the main limitations is that it does not necessarily lead to the production of a theory; instead, it may simply identify and describe a phenomenon without explaining why or how it occurs (Coolican, 2014).

Figure 0.23 Thematic Analysis Stages



(*Note*; Adapted from Braun & Clark 2006)

3.3.2.4. Rigour

When assessing the reliability of study findings, researchers have to judge the 'soundness' of the research and the appropriateness of the methods employed (Noble & Smith, 2015). However, qualitative research cannot be judged by the same quality criteria used in quantitative research, such as internal validity, generalizability, reliability, and objectivity (Korstjens & Moser, 2018). Instead, rigour in qualitative research is assessed through principles of trustworthiness: credibility, transferability, dependability and confirmability, and reflexivity (Korstjens & Moser, 2018; Lincoln & Guba, 1985). The measures used to address these principles in this study are highlighted in Table 3.11.

Table 0.15 Principles Applied to Rigour

Principle	**Research Measures Adopted**
Credibility	Long-lasting engagements during FGDs No sensitive information was obtained, and clarification was sought where necessary.
Transferability	Detailed description of data collection and analysis procedures Recommendations for future research
Dependability & Confirmability	Transparent description of the research path from the project's beginning
Reflexivity	The researcher maintained a balanced relationship with the research process.

3.3.3. Primary Design Dimensions

After describing the data collection methods and designs, it is necessary to emphasise the important characteristics of the design concept within this study. The following sections focus on three important primary design dimensions: the purpose of mixing, integration and weighting.

3.3.3.1. A Review of the Purpose of Mixing

There are various reasons why researchers combine quantitative and qualitative methods within a study. Drawing from Mason (2006) and May (2010), a toolkit designed for the ESRC National Council for Research Methods examines three broad approaches to mixing: **Triangulation, Complementarity, and Constructing multi-dimensional accounts**. A triangulation approach seeks to converge and corroborate results from different data collection methods. The goal of complementarity is to elaborate, enhance, illustrate and clarify results from one method with the results from the other (Schooneboom & Johnson, 2017). When constructing multi-dimensional accounts, it is argued that the complex nature of social phenomena should allow researchers to inquire different but intersecting questions about the subject and to conceptualise what is being researched and what counts as knowledge and evidence in different ways (May, 2010).

The purpose of adopting explanatory sequential mixed methods in this study aligns with complementarity and contrasting multi-dimensional accounts. A relative purpose of developing and expanding is described by Molina-Azorin *et al*. (2016). Firstly, the results from one method in the study design inform the use of the other method. Secondly, the objectives of this study have asked different questions but are conceptualised on the same overall research aim. Thus, a contemporary examination of the challenges and barriers of waste management, assessing the level of public participation, and measuring waste quantities and fractions are all essential components that guide the implementation of WtE. Other design dimensions are explained further in the later sections of this chapter. The following section discusses the integration aspects of the mixed method applied in this study.

3.3.3.2. Data Integration

The most challenging element in the research process is data analysis, especially when done integratively, which is intrinsic to multimethod and mixed methods (Maxwell *et al*., 2015; Onwuegbuzie & Combs, 2010). However, integrating and consolidating different data types during analysis broadens the perspective and permits obtaining complementary views (Vogl, 2019). In a mixed-method study, integration is crucial because it forms the basis of the design to get information from multiple sources to understand a social phenomenon. Hence, the point where the information is brought together may be paramount to the design.

Fetters *et al*. (2013) discuss broadly different approaches to integrating quantitative and qualitative data at three levels: **design, methods, and interpreting/reporting levels**. This study achieved integration at the design level by adopting the explanatory sequential design with quantitative and qualitative methods. Different approaches within the study ensured integration at the methods level. First, by connecting through the purposive sampling for the qualitative phase to build on results in the quantitative phase, and then merging the datasets after independently analysing each phase. A narrative approach was used at the reporting level to weave the quantitative and qualitative datasets after the initial presentation of the quantitative results; this was achieved by linking the quantitative analysis findings to the discussions in the qualitative phase but giving room for further insights, which the purposefully sampled experts best explain.

3.3.3.3. Weighting and Priority

Weighting describes the priority given to the quantitative and qualitative methods within a mixed-method study (Creswell & Plano Clark, 2011). Hence, which method has greater emphasis or drives the study? According to Creswell and Plano Clark, in addition to the research purpose and questions, the decision on weighting or priority is influenced by the worldview guiding the researcher. The two possible weighting options are equal weight, where both the quantitative and qualitative studies have equal priority and unequal weight, where one method (QUAN or QUAL) is more emphasised within the study.

According to the argument put forward by Schooneboom and Johnson (2017), pragmatic philosophy shows that paradigms can be mixed by allowing for equal priority, mainly when the study is conducted to address a superordinate goal. The purpose of mixing in this research was for explanation and understanding, which is the goal of the qualitative phase; hence, it can be argued that this research is qualitatively driven. However, the researcher chose to give equal status to this study's quantitative and qualitative methods. Aside from aligning with the pragmatic underpinning of this research, another reason for giving equal weighting is the interactions between both strands of the mixed methods in the study. Furthermore, Schooneboom and Johnson (2017) argue that a pragmatist researcher demonstrates the possibility of mixing or combining paradigms in an equal-status study, showing that incompatibility does not always apply to the research process. Hence, this research adapts the **QUAN→Qual** label of the equal status design by Johnson and Christensen (2017).

Various researchers in environmental research have previously utilised the concept of equal priority. Revelle et al. (2010) examined environmental practices, barriers and drivers in New Zealand using a sequential explanatory mixed-method design with equal status. Similarly, Rodriguez-Melo and Mansouri (2011) used the same sequential design to investigate the influence of government policies on sustainable development in the construction industry. Therefore, the methods adopted in this study can contribute to knowledge and provide a better understanding of social reality.

3.4. Ethical Considerations

Every step of the research process described in this chapter is guided by the University of Salford code of practice for research. The first step involved satisfying ethical requirements and obtaining ethical approval from the University of Salford (See Appendix A). When data collection commenced, all prospective participants were given all the necessary information about the research to make an informed decision about their involvement. An introductory page led the questionnaire with information on the purpose of the study and an option to proceed or exit the survey. Invitation letters to participate in the FGDs were emailed to the purposively selected participants, and every aspect of consent was addressed in the invitations and at the start of the discussions. In line with the BSA (2017), the researcher employed methods for preserving anonymity by removing identifiers, using pseudonyms, and other technical means for breaking the link between data and identifiable individuals.

3.5. Chapter Summary

This chapter overviews the research design and explains the chosen research methodology using the Saunders Research Onion model. It has outlined the different layers of research philosophy, approaches, methods, strategies, and techniques used for the study, giving justifications where required. The chapter describes the pragmatic philosophical approach, which allowed the use of qualitative and quantitative methods in two distinct phases to explore the current state of waste management in Abuja and examine the challenges, barriers, and prospects for introducing WtE technologies in Nigeria. The next chapter focuses on the quantitative study, the first phase of the explanatory sequential design adopted for this research.

Chapter 4: A Cross-Sectional Survey of Waste Management in Abuja: The Challenges

4.1. Introduction

This chapter introduces **Phase 1** of the sequential explanatory design adopted for this study. The purpose of the quantitative survey was to explore the current state of waste management and examine the challenges and practices of Abuja residents regarding waste management. Waste management is among the critical issues for sustainable development. In order to attain sustainability, it is crucial to implement solid waste management systems that balance the technical specifications with environmental protection goals and the necessities and concerns of various stakeholders, including every socioeconomic class (Wan *et al*., 2019). SDG 12, which aims for responsible consumption and production, has specific targets for effective waste management through prevention, reduction, recycling and reuse (targets 12.4 and 12.5) and minimising food waste (Sharma *et al*., 2021).

The literature indicates that the amount of solid waste generated in Nigeria is growing faster than agencies can develop suitable collection and treatment infrastructure due to various factors, such as urbanisation, legal and illegal construction, population growth, rapid development, and changes in consumption patterns (Debrah *et al*., 2021; Kadafa, 2017); this leads to a strain on the financial and technical resources required to manage the increasing waste. The Nigerian National Policy on Solid Waste Management (FEPA, 2017) draft report acknowledges the urgent need to address the waste crisis. Driven by the need to reduce the dependence on fossil fuels and achieve the SDGs, the government has expressed a keen interest in exploring WtE technologies. However, efficient waste management systems, knowledge of waste characteristics, comprehensive legal frameworks, and the adequate engagement of all stakeholders in waste management are crucial for the success of these technologies.

The critical issues investigated in this study are the challenges faced by developing economies, which are highlighted in the literature (see Section 2.5): low collection rates, unwillingness to pay, poor information and communication, indiscriminate dumping and lack of public participation (Kadafa, 2017; FEPA, 2017). Notably, there is a need for concerted efforts in developing countries to engage members of the public in solving the waste management crisis (Amasuomo, 2015). Hence, this study also examines public participation in the statutory environmental sanitation exercise.

Given this, the study applied quantitative statistical methods to explore waste management in Abuja. The online survey was conducted between January and March 2021. The chapter presents the findings from the analysis of the survey data using the methods outlined in detail in Chapter Three. The research questions guiding the quantitative study are as follows:

RQ1: What is the current state of waste management in Abuja?

RQ2: What sociodemographic and economic factors influence public participation in environmental sanitation in Abuja?

Given these research questions, descriptive and inferential analysis were used to elicit relevant information. Firstly, the demographic and household characteristics of the participants are highlighted before each section of the structured questionnaire is presented. **RQ1** is addressed through a systematic data analysis using Chi-square tests, the Kruskal Wallis test, and Spearman’s Coefficient test to examine relationships and associations. Furthermore, Ordinal Logistic Regression is computed to identify the sociodemographic and economic factors that influence public participation **(RQ2)** within the study area. The concluding part is the chapter summary, highlighting the findings guiding the second phase of the study's explanatory sequential design.

4.2. Survey Distribution and Response Rate

Chapter Three highlights the non-normal distributions of the key demographic variables in this study. The distribution of scores, the standardised skewness, and the kurtosis coefficients revealed significant departures from normality for most variables. The results were outside the normality limits of +/—1.96 (Onwuegbuzie & Daniel, 2002), indicating a serious departure from normality. To confirm this, a Shapiro-Wilk test showed a p-value under 0.05, confirming that the distribution is not normal. As noted in the methodology chapter, 355 responses were initially submitted for the survey. After conducting a thorough data check, it was determined that only 343 responses were valid and included in the final analysis. This information serves as a point of reference for the study and ensures the accuracy of the findings.

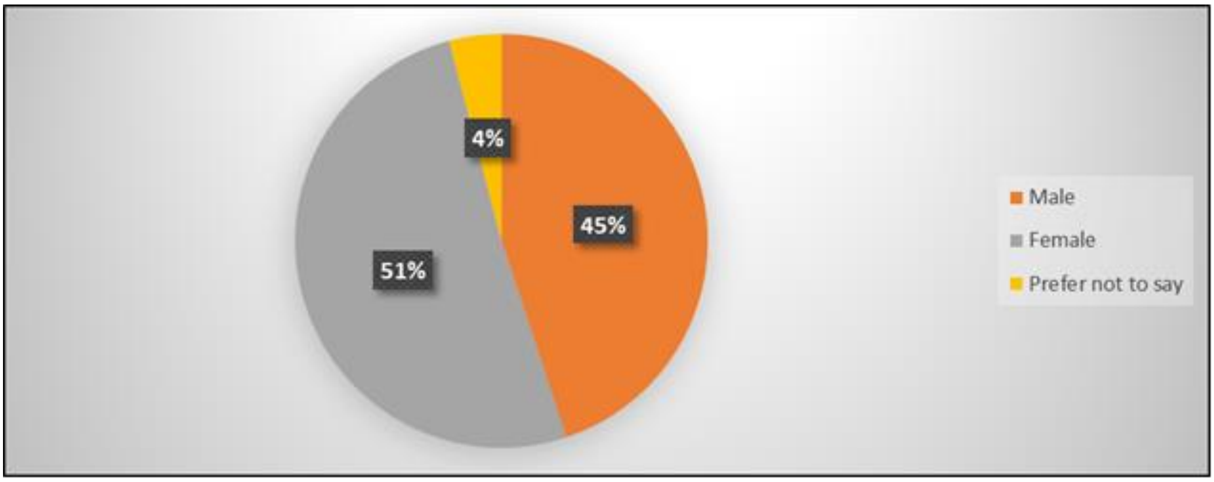
4.3. Demographic Characteristics of Respondents

The first section of the questionnaire captured the participants‘ background information, which provided an overview of the main characteristics of the survey sample. Only characteristics relevant to the study were captured based on the nature of the research and the questions being addressed. The demographic variables included gender, age, employment status, level of education and religious affiliation. Descriptively organising the data was crucial to driving the analysis and improving the reliability and validity of the research (see Table 4.1).

4.3.1. Respondents' Gender

Figure 4.1 represents the gender distribution of the total respondents to the questionnaire survey. The table shows that out of the 343 respondents, just over half (51%) of the respondents were female, while approximately 45% were male. The distribution of respondents deviates slightly from the overall gender distribution in Nigeria, which is 51.5% for males and 49.5% for females (NPC, 2020). Nonetheless, it translates to the sample being a fair representation of the general population regarding gender. Approximately 4% of the respondents chose not to disclose their genders.

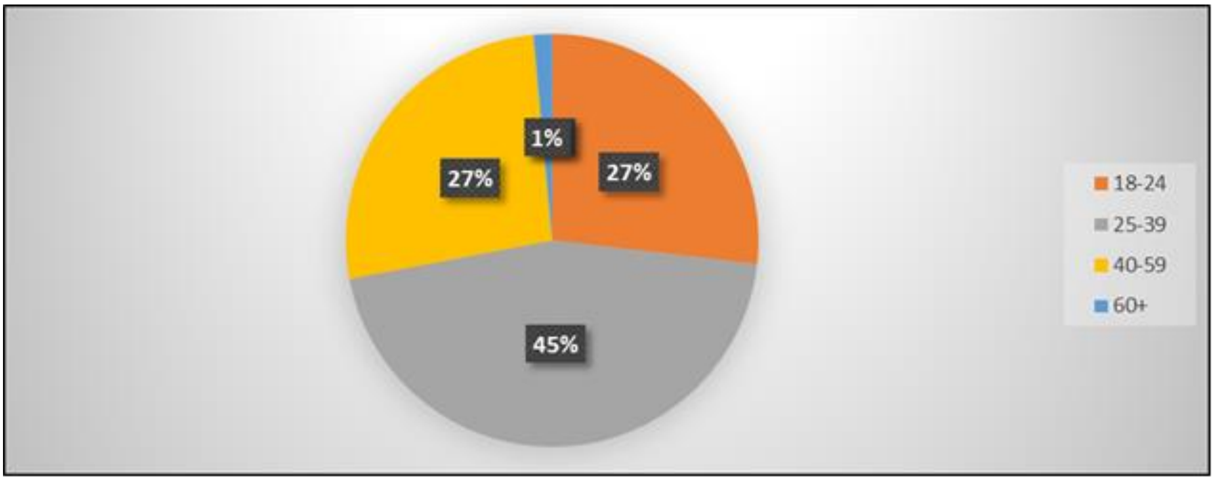
Figure 1.1 *Respondents' Gender Distribution*



4.3.2. Respondents' Age Distribution

Participants were given four options to indicate their age categories. Age was a criterion for eligibility to participate in the survey. Therefore, the ages were 18–24, 25–39, 40–59, and 60 years old and over. The cumulative frequency derived a median age of 25-39 for the sample. Most of the participants (45%) were aged 25-39 years old, followed by those aged 18-24 years old (27%) and those aged 40-59 years old (26%). Approximately 1% of the participants stated that they were 60 or older. The age distribution suggests that the sample group includes individuals in age brackets typically associated with active civic engagement and community participation. In many urban areas, including Abuja City, younger adults are more likely to be involved in various community activities, such as local governance, social organizations, and community development projects.

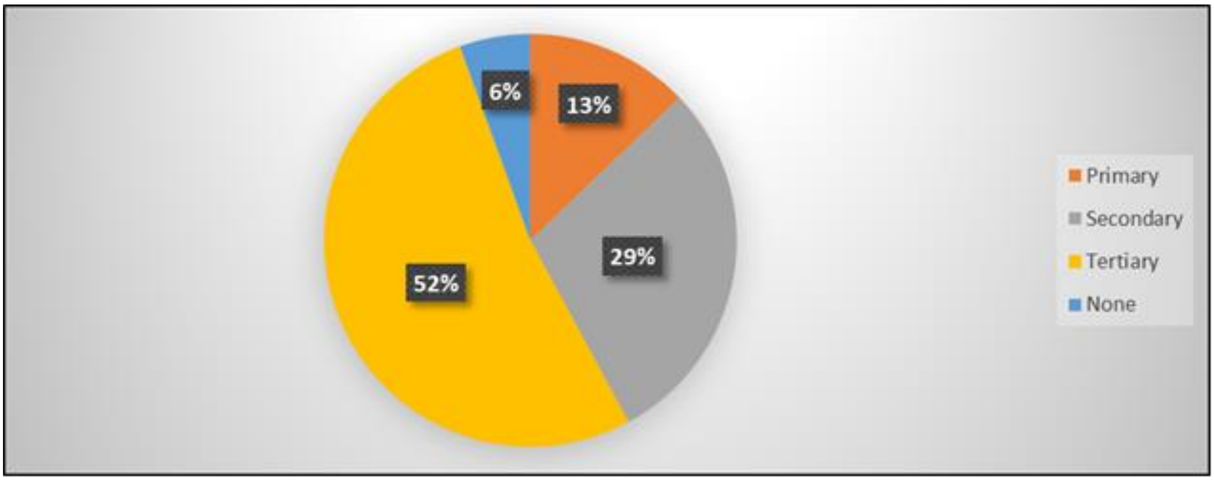
Figure 1.2 *Respondents Age*



4.3.3. Respondents' Level of Education

The respondents were asked to indicate their level of education. Figure 4.3 shows that more than half of the 343 respondents (52%) have been educated up to university level, while 29% indicated to have been educated up to secondary school level. Within the sample, 13% reported having primary education, and the smallest percentage (6%) had not received education.

Figure 1.3 *Respondents' Level of Education*

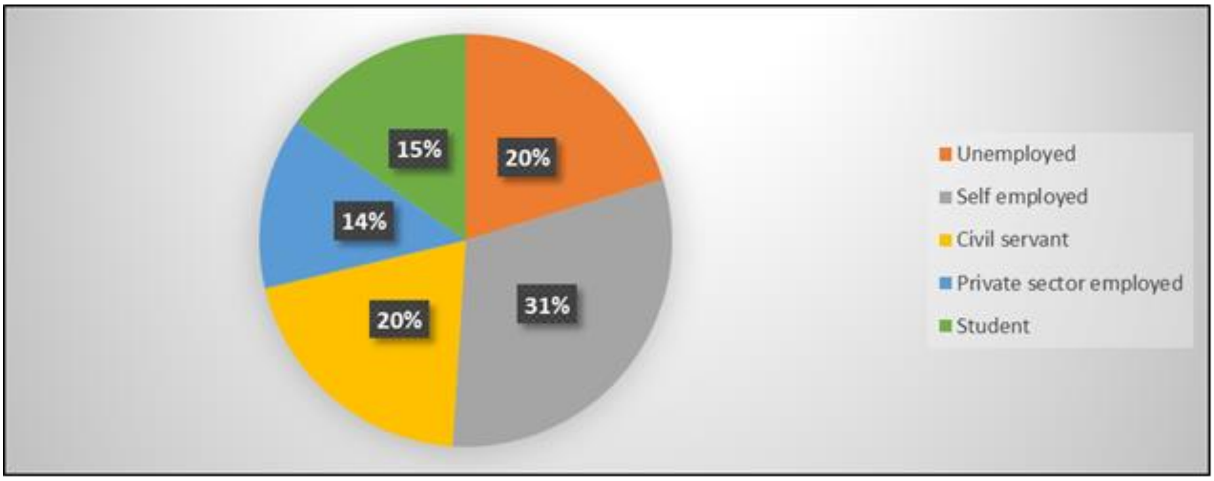


Some authors highlight the effect of education on waste management awareness (Kayode & Omole, 2011; Mamady, 2016). The authors agree that an educated individual or family is more likely to value excellent waste management due to being aware of the negative consequences of poor solid waste management. The distribution agrees with the figures from the National Bureau of Statistics, whose publication shows that Abuja's adult literacy rate is 76.3 %(NBS, 2015). The median level of education for the sample was "Secondary level" (Mdn=2.00), and with more than three-quarters of the respondents (81%) having received post-primary education, it was expected that the participants would respond to questions with a degree of awareness of waste management practices.

4.3.4. Respondents' Occupational Status

The data in Figure 4.4 represent the respondents' occupational status distribution. Most respondents (31%) identified themselves as self-employed, followed by civil servants (20%) and unemployed people (20%). Private sector employees accounted for 14% of the respondents, while students represented 15%.

Figure 1.4 *Occupational Status of Respondents*

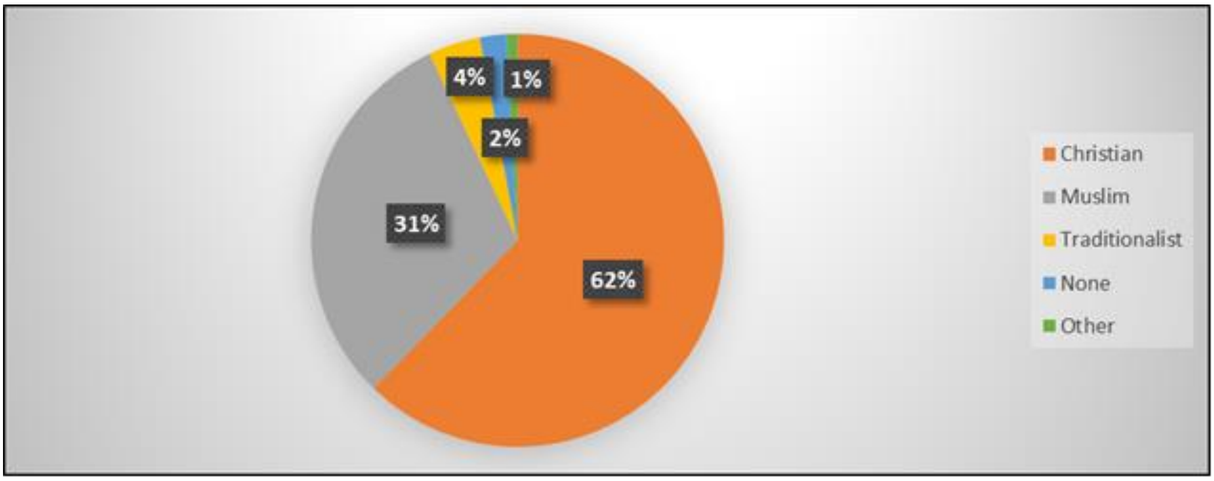


The statistics show that approximately two-thirds (66%) of the sample were income earners. Unemployment is a common issue in Nigeria, as in most developing countries, so the observed frequency in the survey was not surprising. The current unemployment rate in Abuja is 25.4% (NBS, 2020). However, the high migration rate to the city is mostly to earn a living. Many unemployed have resorted to informal waste collection services, leading to increased waste pickers' activities.

4.3.5. Respondents' Religious Affiliations

Religion is a moral compass in guiding the behaviours and actions of individuals and organisations towards the environment, and Nigeria's major religions - Islam, Christianity, and African traditional religions - all prioritise nature conservation, providing a promising opportunity for an effective environmental management system guided by their teachings (Ogunkan, 2012). Furthermore, there is a close link between religion and consumption patterns, influencing practices, waste generation and composition (Gbadamosi, 2021). Abuja has a diverse population, and migration to the city is from most parts of Nigeria, including Lagos, which is primarily overpopulated. Regarding religious affiliations, 62% of the sample was Christians, followed by 31% of Muslims. Approximately 4% of the sample consisted of traditionalists and those with no religious affiliation made up 2%. The smallest proportion of the sample (1%) had other religious affiliations not indicated in the survey instrument.

Figure 1.5 *Respondents' Religious Affiliations*



This section discusses in detail the demographic characteristics of the survey participants in this study. A summary is presented in Appendix F. The following section discusses the respondents' housing and household characteristics, which will be used for further analysis within the study.

4.3.6. Housing and Household Characteristics

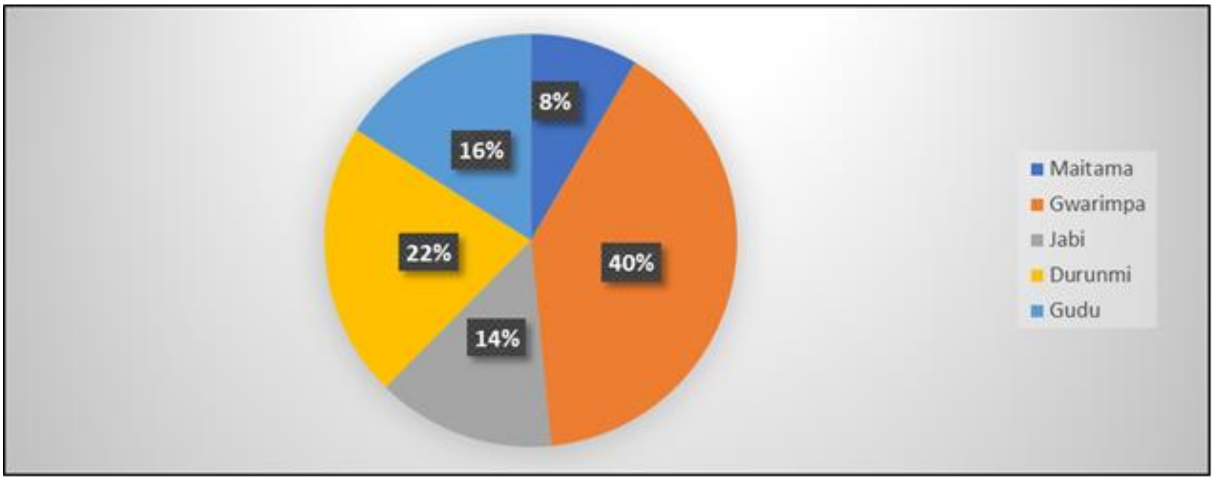
The housing and household characteristics of the sample were measured under three categories: district in Abuja, household size, and accommodation type. As discussed in Chapter Three, accommodation type was an important criterion for stratifying the study area into three socioeconomic parameters: low, middle, and high-income (see Table 3.4 in Chapter Three).

4.3.6.1. Participants' Residential Districts

Table 4.6 shows the distribution of participants in the stratified districts sampled for the survey. The survey results showed that most 343 respondents reside in Gwarimpa, accounting for almost 40% (n=137) of the total. This is not surprising because, like most middle-income areas, Gwarimpa is highly populated and home to mostly working-class individuals, corroborating the high number of income earners within the sample, as discussed in the previous section.

Durunmi and Jabi also had a significant number of participants, with 22% (n=74) and 14% (n=48), respectively. On the other hand, the Maitama and Gudu districts had fewer respondents, with only 8% (n=29) and 16% (n=55), respectively.

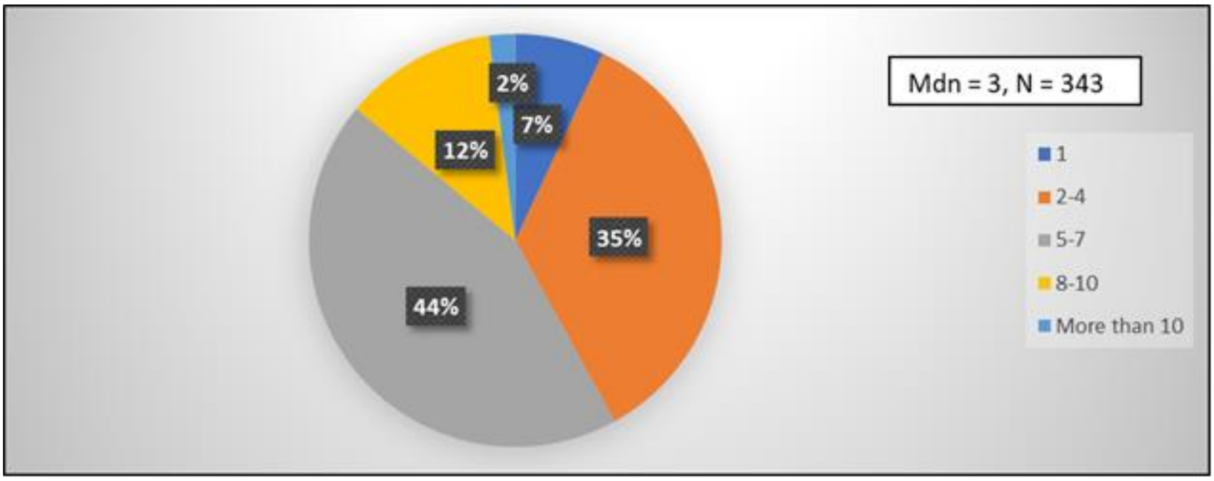
Figure 1.6 *Respondents' Residential Districts*



4.3.6.2. Participants' Household Size

The participants were provided with five options to estimate their household size. The lowest was single occupants, and the highest was those with more than ten occupants. Figure 4.7 shows a graphical illustration of the responses. Most of the sample (46%) indicated the option "5-7"; this is followed by those that selected the option 2-4 (36%). Hence, it can be inferred that the sample generally has a large household size, which translates to a possible high volume of waste generation. The average of "5-7" occupants per household in this study does not deviate from the findings of Njoku *et al*. (2014), who reported an average of six occupants within the Abuja metropolis. As discussed in Chapter Two, Abuja is facing the challenge of urbanisation (Abubakar, 2014), which may be a reason for large households, particularly in predominantly middle-income areas like Gwarinpa. The influx of people, especially in the middle-income and low-income classes, usually searches for jobs and a better lifestyle (Saghir & Santoro, 2018).

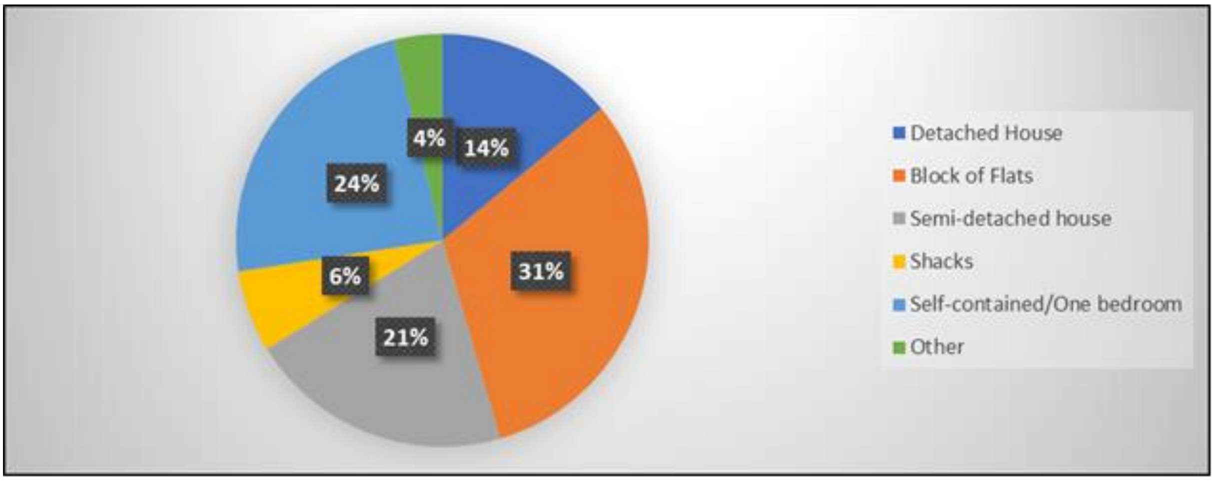
Figure 1.7 *Respondents' Household Size*



4.3.6.3 Type of Residential Building

In this category of the questionnaire item, the participants were asked to select from the available which best describes the type of accommodation they reside in. Most of the samples lived in self-contained/one-bedroom or blocks of flats, each with 27% representation, respectively. A sizeable portion of the sample, 35%, lived in semi-detached or fully detached houses. Those residing in shacks represented 8% of the sample, while 3% lived in other accommodation forms.

Figure 1.8 *Respondents' Residential Building Type*



Those who live in detached and semi-detached homes are assumed to belong to the upper class, while those who live in blocks of flats or self-contained or one-bedroom apartments are considered middle class, and those who live in shacks are considered relatively lower class. However, the respondent's residential district is also a factor in the delineation.

4.4. Assessment of Waste Management in Abuja

In line with the first research question, section two of the survey instrument addressed Abuja's waste management challenges and practices. The challenges surrounding MSWM in developing countries often stem from poor waste collection and disposal techniques (Aliyu *et al*., 2014). Nevertheless, effective waste collection is crucial in managing solid waste and essential to resource recovery. Questions were selected from the literature to assess waste collection within the districts.

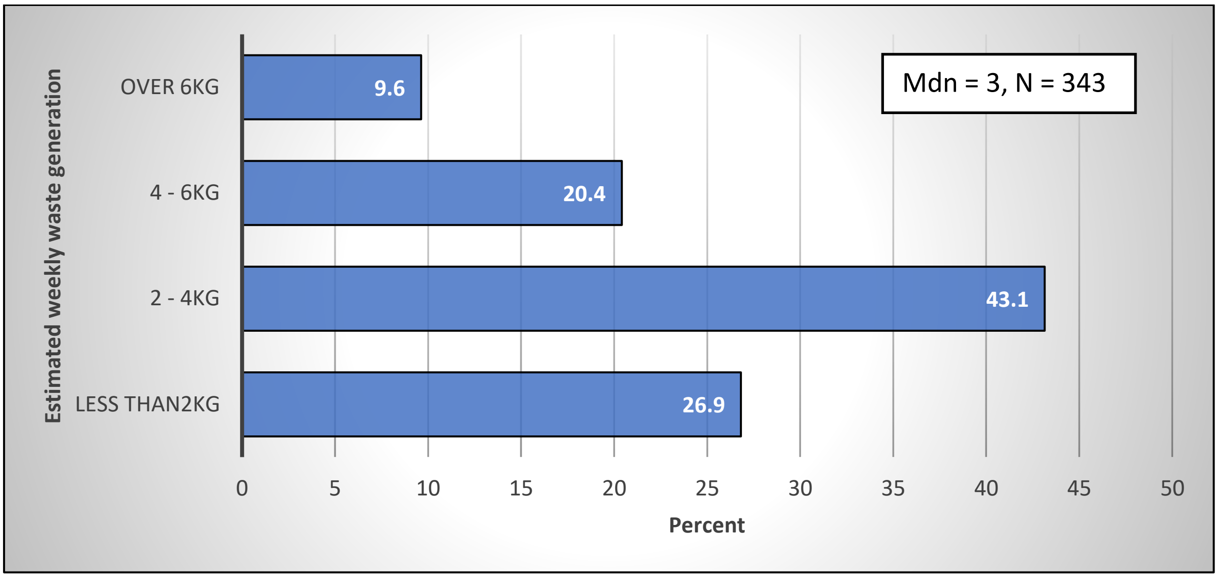
4.4.1. Waste Generation and Composition

The rapid increase in waste generation due to urbanisation, population growth, and the dearth of waste composition data has been discussed in the literature review (see Section 2.2). Hence, after determining the demographic and household characteristics of the respondents, the next section of the questionnaire sought information on estimated waste generation and composition from the respondents; this was useful for the preliminary assessment of the daily waste generation and composition within the sample before Chapter Five's practical waste generation and composition study.

4.4.1.1 Estimated MSW Generation

Four categories of estimates were presented to the participants to estimate how much waste is generated within their households weekly: less than 2kg, 2-4 kg, 4–6 kg, and over 6kg. Approximately 43% of the participants generate 2-4 kg of garbage within their household weekly, while 20.4% reported an estimate of 4-6 kg. About 26.9% of the respondents estimated they generate less than 2 kg weekly, while only 9.6% reported an estimate of over 6 kg. It can be insinuated from the distribution that the sample population generates a relatively high volume of waste. This finding agrees with evidence in the literature that urban centres with large populations generate a high volume of waste (Nnaji 2015; Yusuf *et al.* 2017). However, conclusions are drawn with caution since these were estimates given by respondents. A more detailed generation study is presented in Chapter Five.

Figure 1.9 *Respondents Estimated Weekly Waste Generation*



4.4.1.2 Household MSW Composition

Participants were asked about household composition using five standard waste criteria: food, paper, metals and tins, plastics, and glass. The participants' estimations are analysed and ranked using mean descriptive analysis, as shown in Table 4.1. The participants mostly ranked food as the predominant composition of MSW generated with a mean score (m=2.64, SD=0.051). Paper (m=2.23, SD=0.53), plastics (m=1.99. SD=0.013) and metals and tins (m=1.94, SD=0.012) were ranked second, third and fourth most significant composition.

As expected, glass (m=1.86, SD = 0.127) was ranked as the lowest constituent of the MSW, which may be because of the domestic nature of the sample. This preliminary finding is similar to evidence from previous studies that indicate that organic waste represents the major component of MSW in developing urban cities (Lade *et al*., 2012; Babatunde *et al.,* 2013; Abur *et al.,* 2014; Afuno & Rabiu, 2017, Ezeudu, Ozoegwu & Madu, 2019; Ugwu et al., 2020). However, a primary composition study at the household level was carried out and is presented in Chapter 5. The results demonstrated an opportunity to corroborate the participant's responses on their household waste composition.

Table 1.1 *Respondents Estimated Household Waste Composition*

Component	N	Minimum	Maximum	Mean	Std. Deviation	Ranking
Food	343	1	22	2.64	.051	1st
Paper	343	1	33	2.23	.053	2nd
Plastics	343	1	5	1.99	.013	3rd
Metals & Tins	343	1	7	1.94	.012	4th
Glass	343	1	5	1.86	.127	5th
Valid N	343					

4.4.2. Assessment of Awareness of Waste Management

Participants' awareness of various waste management practices was assessed using Likert scale questions. Five waste management practices centred on the waste hierarchy were chosen from the literature to assess respondents' knowledge: Recycling, Waste Reduction, Reuse, Waste separation and WtE. The responses are categorised into five levels: "Very Poor," "Poor," "Average," "Good," and "Excellent." The descriptive statistics of the variables are presented in Table 4.2.

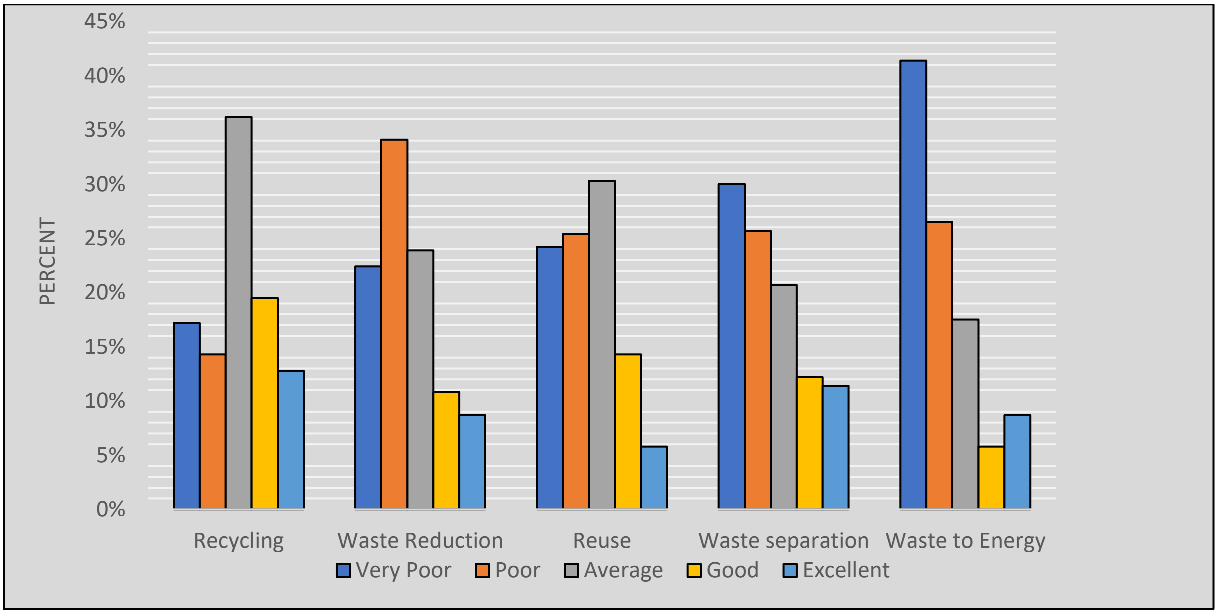
Table 1.2 *Descriptive Statistics for Awareness*

Statistics						
		Recycling	**Reuse**	**Waste Reduction**	**Waste separation**	**Waste to Energy**
N	Valid	343	343	343	343	343
	Missing	0	0	0	0	0
Mean		2.97	2.52	2.49	2.48	2.14
Median		3.00	3.00	2.00	2.00	2.00
Mode		3	3	2	1	1
Std. Deviation		1.242	1.172	1.202	1.335	1.263
Range		4	4	4	4	4
Rank		1	2	3	4	5

The data presented in Figure 4.10 shows that when asked about their recycling awareness, most respondents rated their understanding as "Average" (36.2%), indicating a moderate level of comprehension. However, a significant number of participants rated their perceptions as "Very Poor" (17.2%) or "Poor" (14.3%). On the other hand, some respondents expressed good understanding, with 19.5% rating it as "Good" and 12.8% as "Excellent. Regarding waste reduction, many respondents rated their perception as "Poor" (34.1%), indicating a lack of understanding and implementation of waste reduction strategies. A notable percentage also rated their knowledge as “Very Poor” (22.4%). However, some respondents rated their understanding as “Good” (10.8%) and “Excellent” (8.7%). Responses on reuse were more evenly distributed. While a significant number of respondents rated their awareness as "Average" (30%),” there were also considerable proportions who considered their awareness as “Poor” (”5.4%) and “Very Poor” (4.2%). A smaller percentage rated their knowledge as “Good” (14.3%) and “Excellent” (5.8%).

Regarding waste separation, a notable percentage of respondents rated their knowledge as “Very Poor” (30.0%) and “Poor” (25.7%), indicating a lack of understanding of proper waste segregation. However, some respondents expressed better knowledge, with 12.2% rating it as “Good” and 11.4% as “Excellent.” The practice of WtE received the highest proportion of “Very Poor” ratings (41.4%), suggesting limited awareness about energy recovery from waste. While a significant number rated their knowledge as “Poor” (26.5%), there were smaller percentages who indicated “Average” (17.5%), “Good” (5.8%), and “Excellent” (8.7%) knowledge.

Figure 1.10 *Respondents’ Awareness of Waste Management Practices*

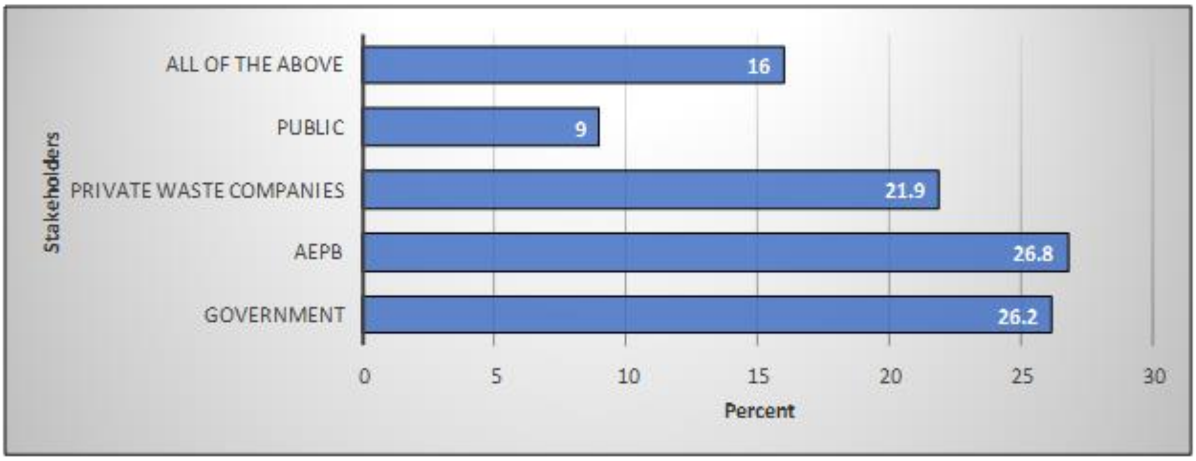


Based on the data in Table 4.4, the survey respondents had a greater understanding of recycling (Mdn = 3.00) and reuse (Mdn = 3.00). However, there are indications of a significant gap in their knowledge and understanding of waste management practices; this is surprising given the participants' education level. Interestingly, these findings contradict the results reported by Kadafa (2017), who found a positive correlation between education level and knowledge of waste management practices; this may suggest that being educated does not necessarily translate to knowing waste management practices. Notably, the respondents have little knowledge of the potential for energy recovery from waste. Therefore, sensitisation must improve to enhance waste education and awareness and promote better understanding and practices. Applying a knowledge management approach and strategy is crucial for inculcating a change of attitude towards improving waste management (Abila & Kantola, 2013).

4.4.2.1. Waste Management as a Responsibility

The respondents were asked who they think should be responsible for waste management. Five options were given: “Government,” “AEPB,” “Private Companies,” “Public,” and “All of the above.” According to the survey results, the majority of participants (26.8%) feel the municipal agency, AEPB, should be responsible for waste management. Another 26.2% believe waste management is the Government’s responsibility. Private waste companies were also popular, with 21.9% of respondents selecting it, while “Public” received a lower response rate of 9.0%. Interestingly, only 16.0% of participants understood that waste management is the responsibility of all the stakeholders mentioned in the options.

Figure 1.11 *Responses to “Who should be responsible for Waste Management?”*



4.4.3. Assessment of Waste Collection

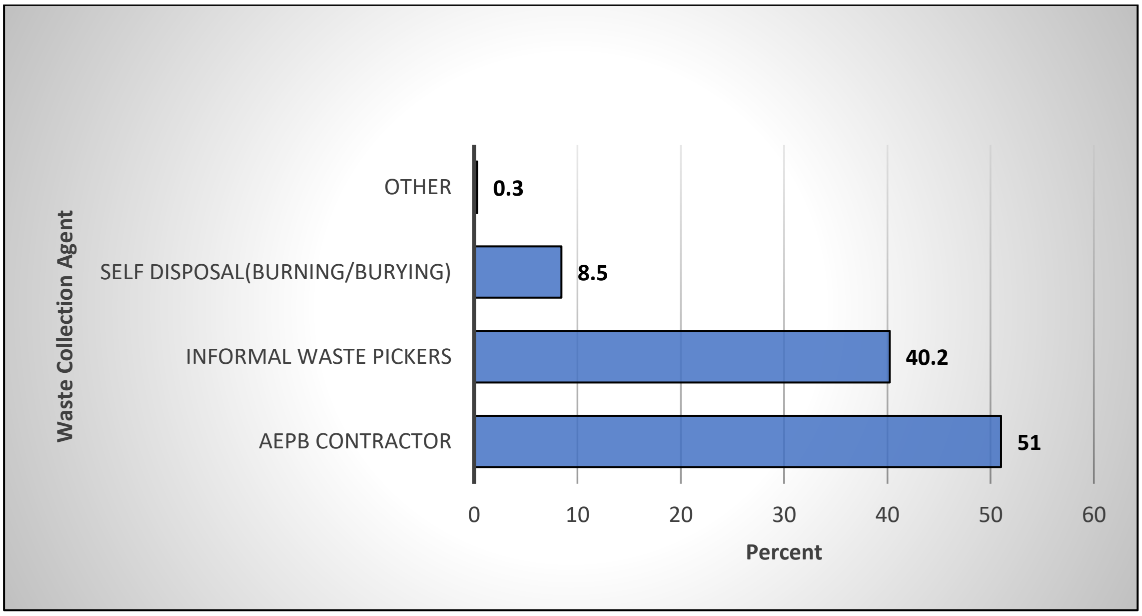
Waste collection has become a primary concern worldwide, as urbanisation and population growth have significantly increased the amount of waste produced

(Hannaan *et al*., 2020). As Chapter 2 mentions, waste disposal and collection present significant obstacles in developing nations. Studies suggest that collection rates are notably low in several Nigerian cities, as only 25-40% of waste is collected for disposal (Hammed *et al*., 2016; Amusan *et al*., 2018). AEPB has registered contractors under PPP arrangements who are contracted to collect waste from the municipality. These contractors work directly and report back to AEPB, while AEPB focuses on managing the waste dumps and collection in the peripheral parts of the FCT.

4.4.3.1. Waste Collection Agents

It was essential to determine who is responsible for household waste collection in different districts to assess the effectiveness of waste collection. The participants were provided with four options: AEPB contractors, informal waste pickers, and "self" for those who, in some cases, burn their waste. "Others was a fourth option in case respondents disagreed with the provided options. The data in Figure 4.12 revealed that the majority (51%) of the respondents collect waste through AEPB contractors, followed by informal waste pickers, who collect from approximately 40% of the respondents' households. Only 8.5% of the respondents agreed to handle waste disposal themselves, while a small proportion (0.3%) indicated "others."

Figure 1.12 *Responses to "Who is responsible for Waste Collection?"*

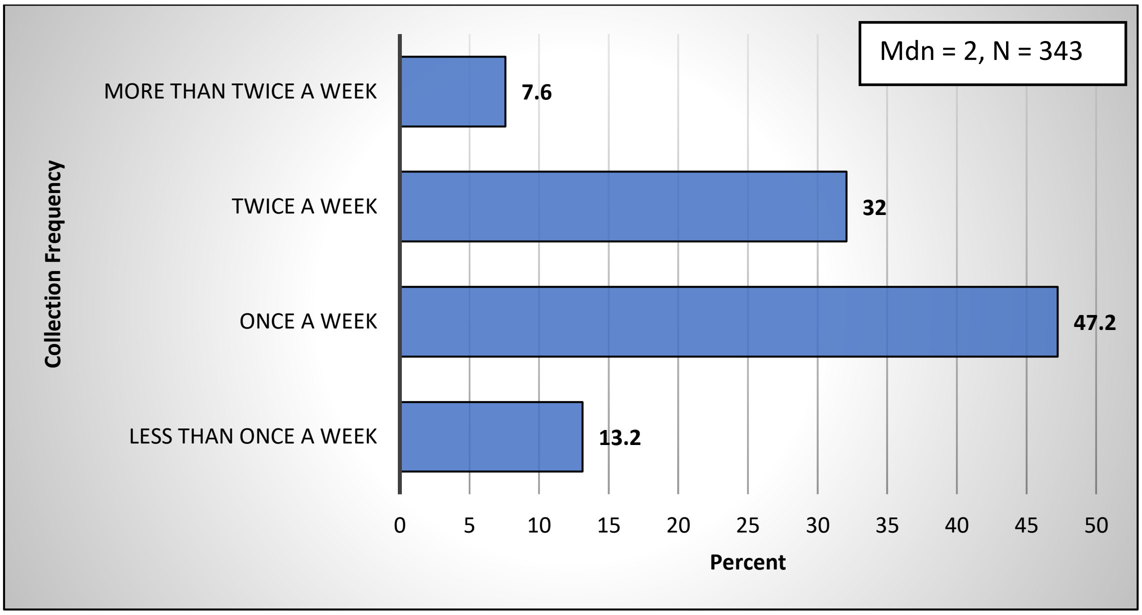


The findings are consistent with the reports from other studies, such as those by Kadafa (2017), which indicated that AEPB is responsible for most waste collection within the Abuja metropolis. However, when comparing the reported proportion for informal waste pickers, this study's results suggest that informal waste pickers' activities have increased. The increase in the activities of informal waste pickers means that the MSW collection has provided many artisans with economic benefits (Nduneseokwu *et al.,* 2017). Since waste pickers/collectors are mainly after recyclables, this noticeable increase in their activities may suggest enhanced awareness of waste's value as a resource.

4.4.3.2. Waste Collection Frequency

The survey respondents were asked to estimate the frequency of household waste collection. Figure 4.13 shows that just under half of the respondents (47.2%, n=162) reported that waste collection is once a week, while 32% (n=110) and 7.6% (n=26) indicated twice and over two times a week, respectively. On the other hand, 13.2% (n=45) of the respondents indicated that more than a week passes without waste collection. The results agree with the study by Kadaffa (2017), whose survey reported 45% for collection once a week and approximately 21% twice a week. The more frequent collection rates mean that some areas that generate more waste are serviced more regularly. It has also been suggested that income level may be a factor in waste generation, with some arguing that higher-income households produce more waste (Ogwueleka, 2013). The need for coordination of the waste collection activities has been reported by Imam *et al*. (2008). Since there is no collaboration with the informal waste pickers who roam the different districts collecting household waste to retrieve recyclables, households serviced by AEPB contractors could also be visited

Figure 1.13 *Responses to Waste Collection Frequency*

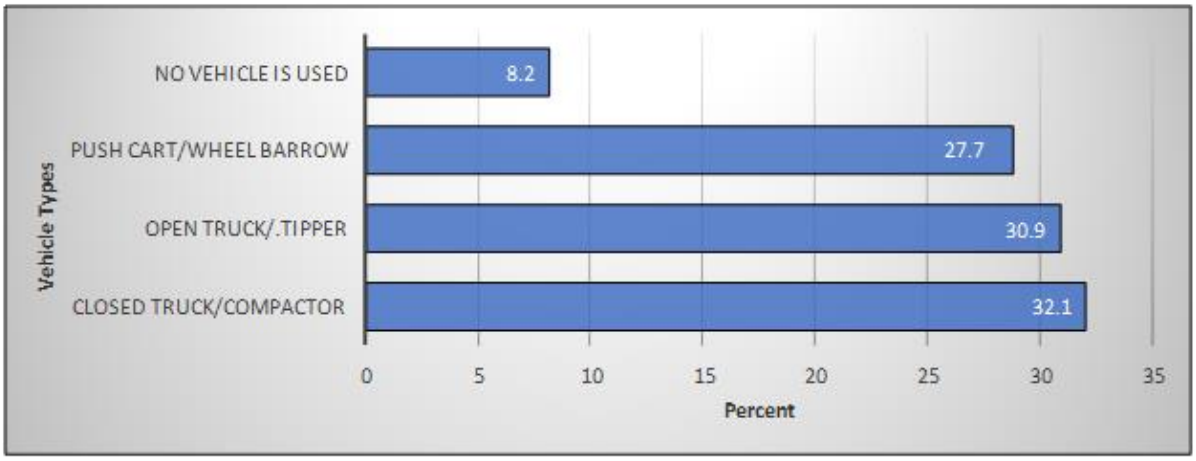


The waste collection once a week cannot be deemed satisfactory considering the general perception and accounts in the literature that the waste composition is primarily organic (Imam *et al*., 2008; Nnaji, 2015; Yusuf *et al.,* 2017). One major problem with organic waste is its adverse health and environmental effects. Rotting food smells awful and attracts pests if allowed to sit for long periods. The organic decay process is accelerated due to higher temperatures (Latif *et al*., 2012) in warmer climates.

4.4.3.3. Waste Collection Vehicle Types

After assessing the waste collection frequency, the respondents were asked to indicate the kind of vehicles used for waste collection from their households. The statistics in Figure 4.14 reveal that most respondents (32.1%) reported closed trucks or compactors, followed closely by open trucks at 30.9%. A considerable number (27.7%) indicated push carts or wheelbarrows, while a smaller percentage (8.2%) indicated that vehicles are not used for waste collection from their households. The data pattern followed a similar trend and supported the observations in the previous section, where respondents were required to identify who was responsible for their waste collection. Compactors and open trucks are vehicles operated by AEPB contractors (Imam *et al*., 2008). Hence, this confirms that AEPB is responsible for most of the waste collection. Interestingly, similar statistics are observed for those who indicated “no vehicle is used” (8.2%) and those in the previous section who personally handed their waste disposal (8.5%); this was a good indication of the validity of the survey responses.

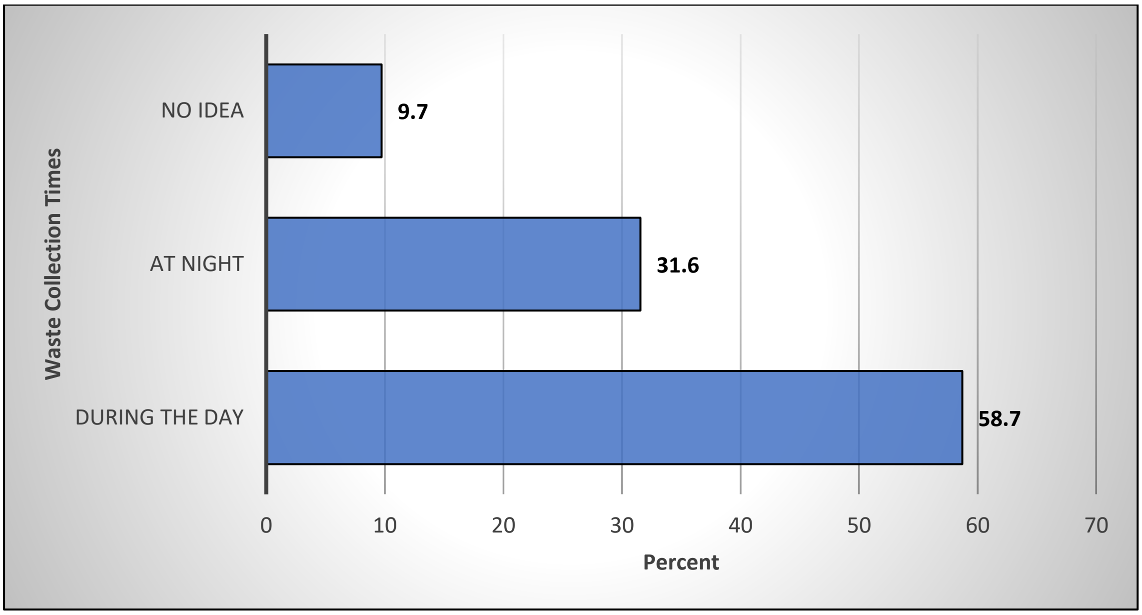
Figure 1.14 *Responses to Waste Collection Vehicle Types*



4.4.3.4. Waste Collection Time

Figure 4.15 presents the results for the question designed to determine waste collection time. Abuja is a large city with a rapidly increasing population, which results in many commercial activities; this has also influenced the transportation system by increasing the number of vehicles within the city. Hence, understanding the effects of waste collection time was necessary as it can be important for route planning, waste collection scheduling, and inferring the collection rate.

Figure 1.15 Responses to Waste Collection Time

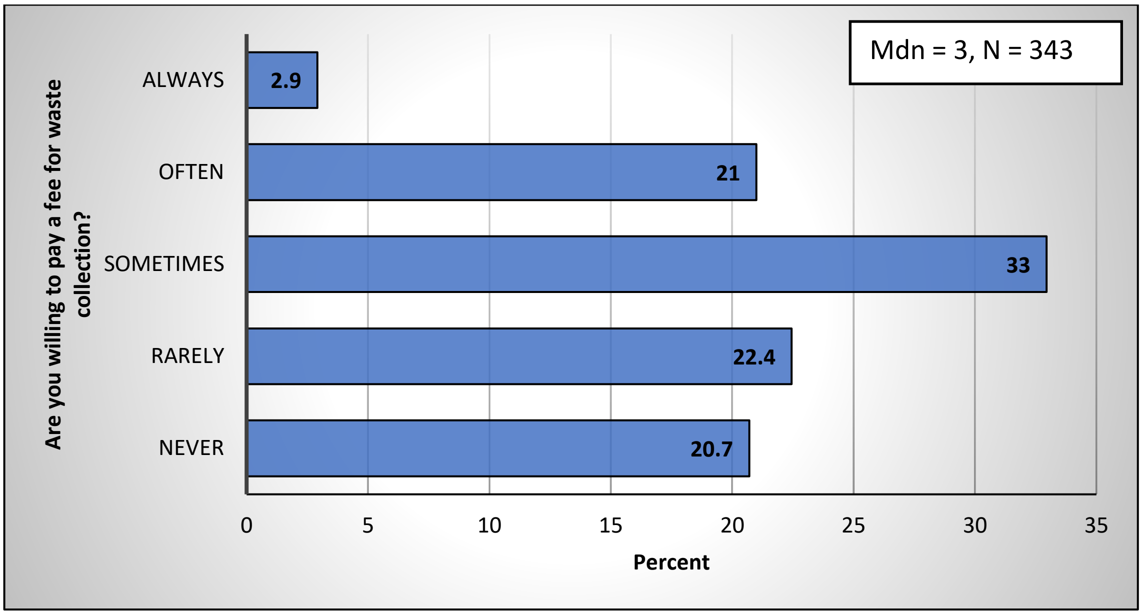


The details that emerge from the results show that among the respondents, the majority (58.7%) indicated that waste collection occurs during the day, while 31.6% stated that it occurs at night. On the other hand, approximately 9.7% reported having no idea about the specific time. Hence, waste collection is primarily done during the day.

4.4.4. Assessment of Willingness to Pay for Waste Collection Services

According to Odama (2012) and the JICA report (2018), the monthly rate service charge for waste collection services is stipulated in the "Waste Management Rates/Charges Regulation 2012". The fees vary based on two classification factors: residential building type and residential district; hence, some districts are charged more than others. Residents are expected to make payments for waste services to AEPB each month at the end of the month. The issue of payment for waste management services in Abuja is highlighted by Onyanta (2012), who reports that the method taken by the AEPB in determining user charges disregards the critical nature of affordability, which may be a contributing factor in the unwillingness to pay for the services. Respondents were asked if they would pay for waste collection services to gain insight into the payment issue.

Figure 1.16 *Responses to Payment for Waste Collection*



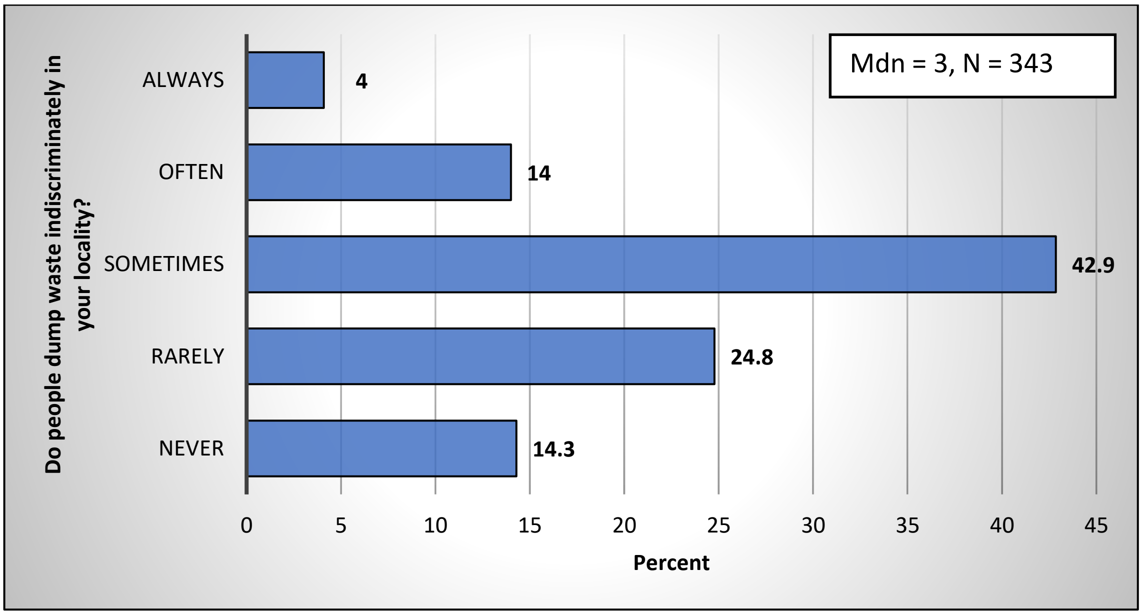
The statistics in Figure 4.16 show varying levels of willingness among the respondents. Most respondents (33%) reported sometimes, while (22.4%) indicated that they are rarely willing to pay for waste collection services. However, 20.7% of respondents are never willing to pay. Notably, a smaller proportion of the sample indicated willingness to pay, as 21% of respondents said often, and a mere 2.9% said always; this highlights a need for better awareness and communication on the benefits of compliance. The unwillingness to pay for waste services has been reported as a significant challenge, especially for the private contractors that depend solely on these payments to function effectively (Kwatra *et al.,* 2014); this may lead to infrequent collection due to a lack of funds. Hence, the outcome may further explain the results in the previous section that showed a high level of waste collection by informal waste pickers.

4.4.5. Assessment of Open Dumping

The issue of open dumping, mostly in developing countries, has widely been discussed in the literature (see Sections 2.3 & 2.3.1). Various authors have also reported indiscriminate dumping in Nigeria and related it to poor waste attitudes, population growth, waste generation increase and low collection rates (Imam *et al*., 2008; Kadafa, 2017). It was, therefore, necessary to explore the issue of indiscriminate dumping among the study respondents. However, investigations into such non-pro-environmental issues are problematic due to the topic's sensitive nature. Respondents are always reluctant to admit harmful practices and over-report acceptable responses to the broader society (Grimm, 2010). This issue of pro-environmental reporting and social desirability bias is highlighted in Chapter Three (see section 3.3.1.4).

Following recommendations from the literature (refer to section 3.3.1.4), an indirect question was used to elicit information about open dumping (see Figure 4.17). The results show that when asked if indiscriminate dumping is observed in their localities, 14.3 % said “Never”, and 24.1% said “Rarely”. However, 49.9% indicated “Sometimes”, meaning that it is not strange for people to dump waste in their districts. At the same time, the remaining respondents admitted it is common practice, with 14% reporting “Often” and 4% “Always”. The finding further supports the initial argument that open dumping of MSW is still a significant problem in Abuja; this agrees with the findings from previous studies that reported the practice of indiscriminate dumping along roadsides, open pits, and water channels in different parts of the city (Raimi *et al.,* 2019; Yusuf *et al*., 2019)

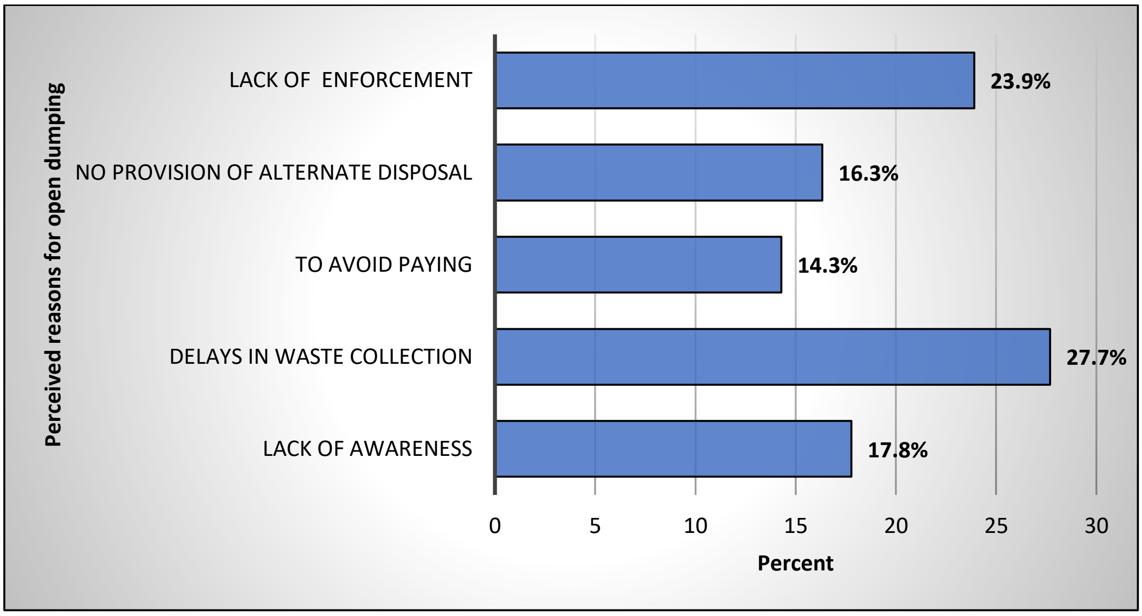
Figure 1.17 *Responses to Indiscriminate Dumping*



4.4.5.1. Respondents’ Perceived Reasons for Open Dumping

Respondents were asked why they think people dump waste indiscriminately as a follow-up to the question on open dumping. The survey participants highlighted several significant reasons for the waste management problem. The most common perceived reasons (Figure 4.18) were delayed waste collection (27.7%), inadequate enforcement (23.9%), and insufficient awareness (17.8%); this indicates that inefficient waste management procedures, such as irregular collection schedules and inadequate enforcement measures, play a substantial role in causing the problem. Furthermore, respondents also blamed the avoidance of paying waste collection fees (14.3%) and the lack of alternative disposal options (16.3%) as contributing factors.

Figure 1.18 *Respondents Perceived Reasons for Indiscriminate Dumping*



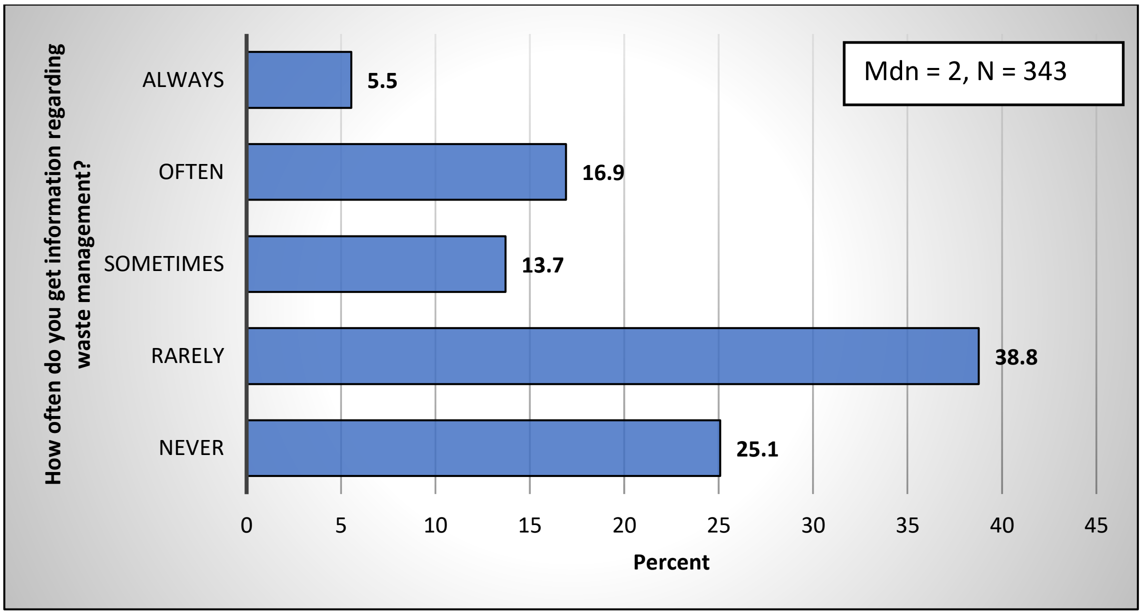
However, the issue of lack of knowledge needs to be examined critically. It may be misleading to say people lack knowledge because much of this practice is done during the night to avoid being seen; this indicates that there is an understanding that open dumping is against the law and may attract a penalty or fine. Instead, it may suggest a degree of dissatisfaction with waste management services or indicate a lack of enforcement or alternative collection infrastructure.

4.4.6. Assessment Information and Communication on Waste Management

Public information and communication are fundamental to the success of any waste management system (Stepien & Bialecka, 2015). It is a good way for the government to show it recognises the public as stakeholders and part of the waste management system. The most common intervention is to provide information (Wan *et al*., 2019). By sharing information about waste problems, individuals can become more aware and knowledgeable about the issue and learn about potential solutions to address the problem. Despite the importance of information and communication in creating public awareness, little literature stresses the importance, especially in Nigeria. It was therefore important to inquire how often participants receive information and communication on waste management issues.

The results (see Figure 4.19) show that most respondents (38.8%) rarely receive information about waste management activities, and 25.1% indicated they never do. A smaller proportion of the sample indicated receiving information frequently, with 16.9% saying "Often" and 5.5% saying "Always". Although 13.7% of the respondents receive information sometimes, the statistics indicate a potential gap in communication on waste management activities based on the significant proportion who receive limited or no information about waste management. Overall, the results indicate a paucity of information among respondents as most respondents (<60%) rarely or never receive information on waste management issues.

Figure 1.19 *Responses to Frequency of Information*



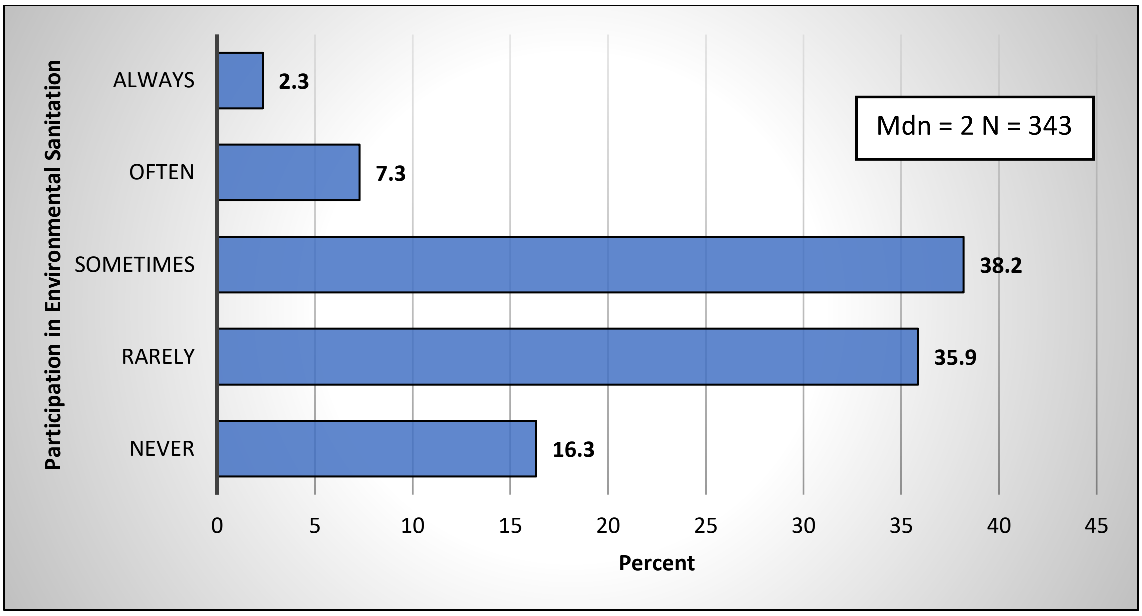
4.4.7. Assessment of Public Participation in Environmental Sanitation Exercise

When investing in MSWM, it is crucial to consider the needs and preferences of all stakeholders; this involves considering factors such as service delivery, costs, and potential environmental and social outcomes. To achieve effective waste management, involving the public in decision-making is essential. Shukor *et al*. (2011)

emphasise the importance of public awareness and participation in achieving success in this area. As highlighted in the literature review (see Section 2.8), the environmental sanitation exercise is a crucial government intervention in improving sanitation in Nigeria on the last Saturday of every month. Municipalities enforce it, and participation is compulsory except for essential workers who will be on duty. Despite efforts by the government, many people are reluctant to participate and feel the event does not contribute to solving waste management and sanitation issues (AEPB, 2012).

The data in Figure 4.20 reveals that a significant portion of the respondents (35.9%) reported participating rarely, indicating low interest in the Environmental Sanitation exercise. Moreover, only 2.3% of the respondents reported always participating in the exercise, indicating a relatively small proportion of individuals demonstrating high commitment. On the other hand, a considerable number of respondents (38.2%) reported participating sometimes, suggesting intermittent engagement with the Environmental Sanitation exercise; this may reflect a degree of awareness and willingness to contribute to environmental cleanliness but not to the extent of routine participation. A small proportion of the sample never participated (16.3%) and often participated (7.3%) in the exercise. These findings may indicate the need for targeted efforts to increase awareness, education, and motivation to promote more consistent and widespread participation in Environmental Sanitation practices for the overall well-being of the environment.

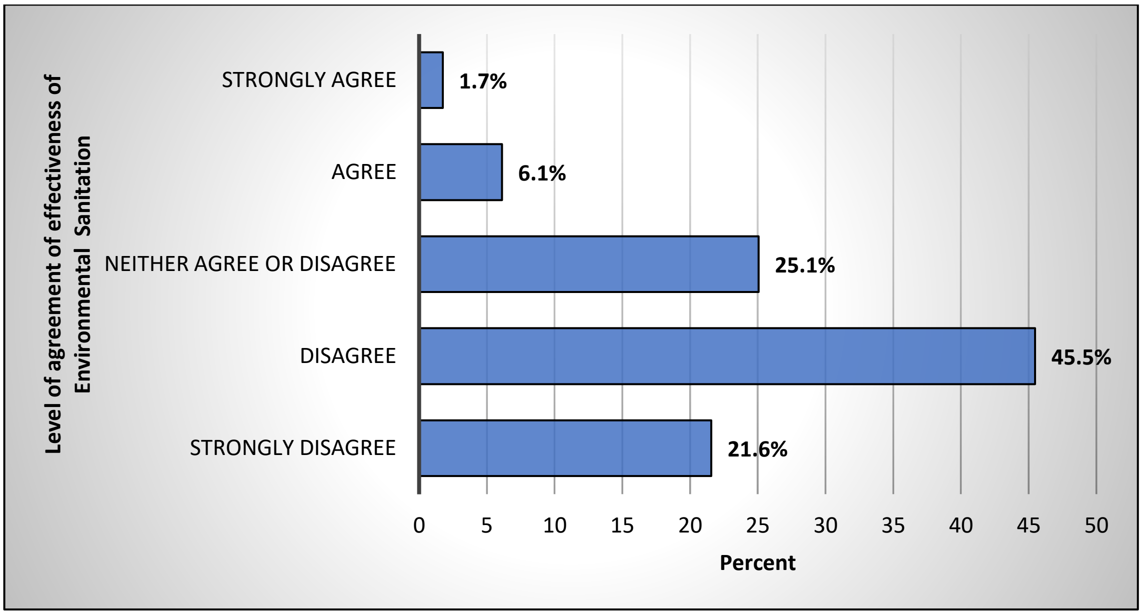
Figure 1.20 *Respondents' Participation in Environmental Sanitation Exercise*



4.4.7.1. Effectiveness of Environmental Sanitation

Participants were then asked if they agreed that the environmental sanitation exercise was effective. The results in Figure 4.21 show that a significant proportion (45.5%) of the 343 respondents disagreed that environmental sanitation is an effective waste management strategy in Abuja, and an additional 21.6% strongly disagreed. On the other hand, only 6.1% agreed with the effectiveness of environmental sanitation, with 1.7% strongly agreeing. The remaining 25.1% of respondents neither agreed nor disagreed. The findings indicate that most study participants (67.1%) do not consider environmental sanitation an effective waste management strategy.

Figure 1.21 *Level of Agreement on Effectiveness of Environmental Sanitation*

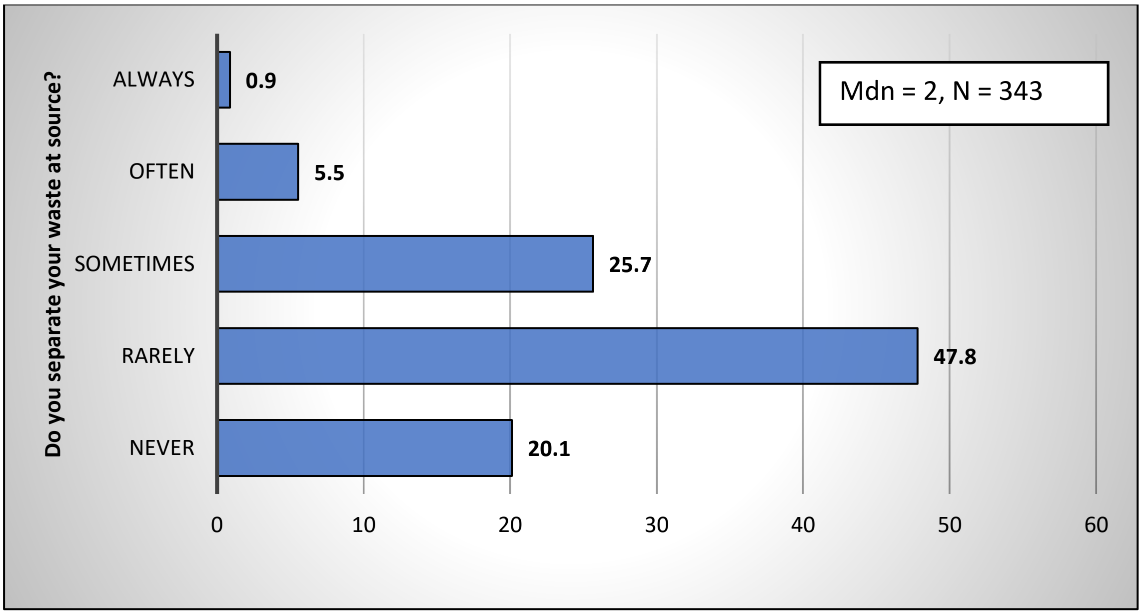


4.4.8. Assessment of Waste Management Practices of Respondents

4.4.8.1. Source Segregation

Segregation of waste at source plays a key role in energy recovery. However, it requires sustained sensitisation and participation of individuals and institutions generating the waste. According to Ogwueleka (2013), there is little or no segregation of waste at the source level in Abuja, which has resulted in multiple environmental issues, primarily due to the organic nature of the waste generated in the city. It was, therefore, necessary to investigate segregation practices among respondents. When the respondents were asked if they separate different types of waste into separate bins or containers, Figure 4.22 shows that out of 343 respondents, the majority (47.8%) indicated that they rarely segregate their waste; this suggests that they do not consistently sort food, paper, and plastics into separate bins. Another 25.7% reported doing it sometimes, and a smaller percentage of respondents reported higher frequencies of waste separation. Only 5.5% indicated they often throw different kinds of waste in different bins. Furthermore, 0.9% reported always separating their waste, indicating a consistent and committed approach to waste segregation.

Figure 1.22 *Respondents' Source Segregation Practices*

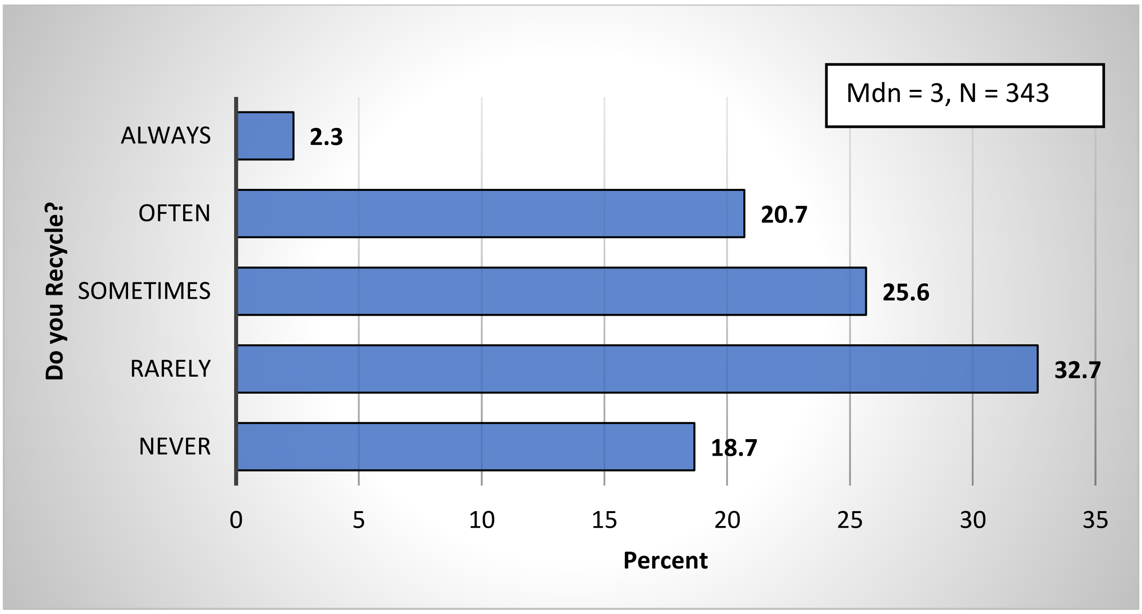


A summary of the results suggests that most respondents (67.9%) do not currently segregate their waste; this may show the need to educate people and promote waste segregation to improve participation (Kala & Bolia, 2021).

4.4.8.2. Recycling

Materials recycling activities in the Abuja municipality are mainly limited to household reuse and scavenging activities of low-income dwellers since AEPB has no formal recycling programme or strategy and no other materials recovery facility exists in the city (Agbaeze *et al*., 2021; Ofobruku & Ezeah, 2019). Therefore, it was necessary to know if the participants recycled waste at the household level. Figure 4.23 presents the findings regarding recycling by the respondents. The Figure reveals that 18.7% of the respondents indicated they never recycle items. On the other hand, a significant number of individuals demonstrated positive recycling behaviours, with 32.7% stating that they rarely engage in recycling, 25.7% reporting occasional recycling, and 20.7% indicating frequent recycling. Notably, a smaller proportion, comprising only 2.3% of the participants, indicated they always recycle waste.

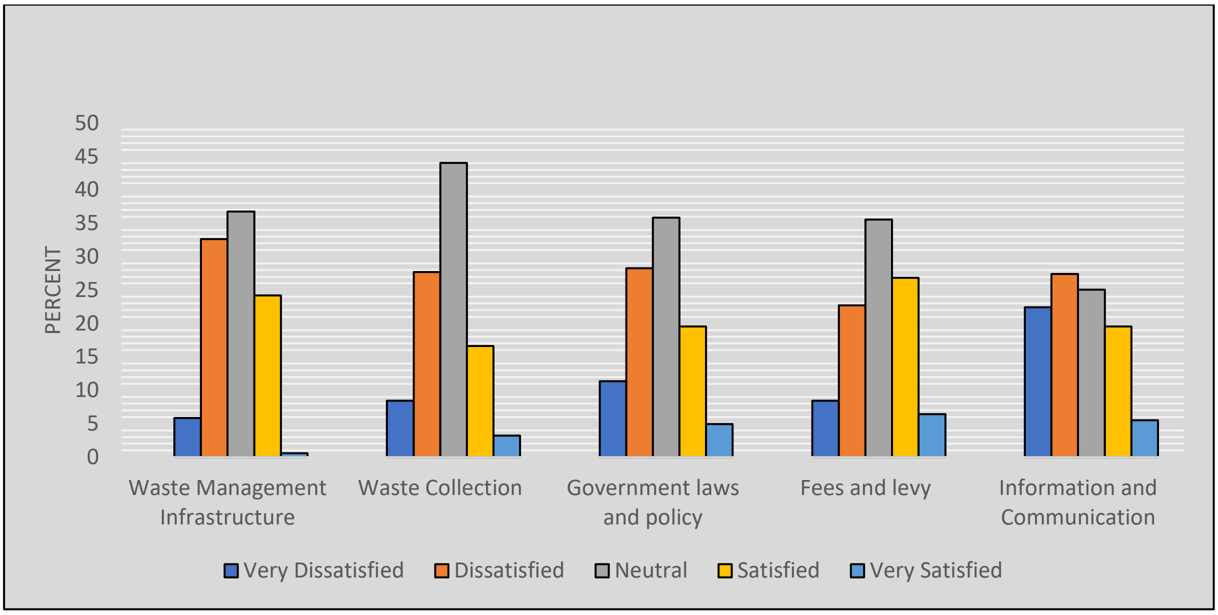
Figure 1.23 *Responses to Recycling*



4.4.9. Respondents' Level of Satisfaction

The last question in the survey examined the participants' level of satisfaction with different aspects of waste management. The categories were "waste infrastructure", "waste collection", "government laws and policies", "Fees and levy", and "information and communication". The results in Figure 4.24 show high levels of dissatisfaction among the respondents, as the majority of the respondents indicated being either dissatisfied or very dissatisfied with waste infrastructure (38.5%), government laws and policies (39.7), and information and communication (49.8%). The results reveal that even when more of the respondents chose to be neutral (neither satisfied nor dissatisfied), like for waste collection (44%) and fees and levy (35.6%), they indicated high levels of dissatisfaction (36.2% and 31.2%, respectively). However, the most satisfaction observed compared to other categories was 33.2% (satisfied and very satisfied) for collection fees and levies, which was higher than those either dissatisfied or very dissatisfied (31.1%). However, a larger proportion (36%) of the respondents were neutral about their fee satisfaction.

Figure 1.24 *Responses to Level of Satisfaction*



4.5. Inferential Analysis of Survey Data

This section presents the inferential analysis of the sample data. In line with **RQ1,** a district-level waste management assessment was performed using non-parametric statistical tests. The objective was to explore and compare patterns of waste management challenges and practices among the districts, which can identify the need for different strategies in tackling waste management issues in Abuja. The researcher carefully chose tests that fit the variables' characteristics and ensured that all assumptions for each test were satisfied before proceeding. Chi-square tests were conducted to assess the relationship between two nominal variables. A Kruskal-Wallis test was conducted for nominal and ordinal associations. Spearman's Correlation was utilised to analyse the relationships between ordinal variables further.

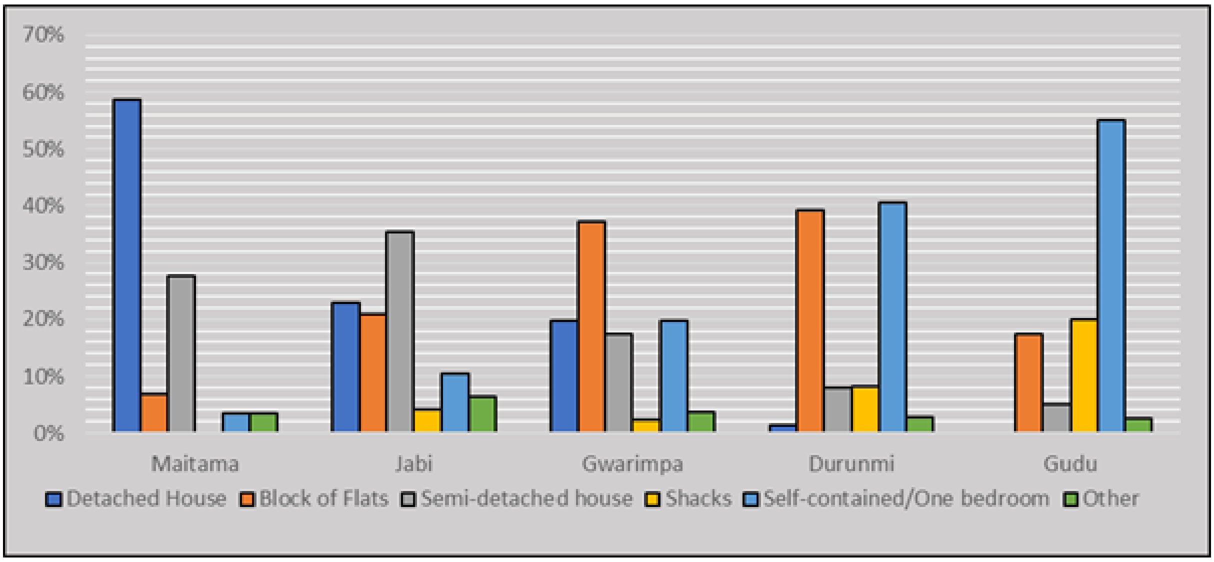
4.5.1. Assessment of Waste Management Challenges and Practices by District Using Chi-square Test

Chi-square tests were performed to explore the relationship between the respondents' residential districts and the nominal variables, such as residential building type, waste collection agents, and collection vehicles. Cross tabulations preceded each test to observe the distribution of the variables between the districts. Cramer's V (ϕ) was used to measure the effect size of associations, and the residential district was set as the independent variable for each test.

4.5.1.1. Residential Building Type by Residential District

To support the argument about the socioeconomic classification of the districts, a correlation between the type of residential buildings and the respondents' districts was examined through a Chi-square test. A summary of the cross-tabulation results between the variables shows that approximately 58.6% of respondents living in Maitama reside in detached houses. In contrast, most respondents (37.2%) live in Gwarimpa in blocks of flats; this is not surprising since Maitama is a relatively high-income area, and residents are affluent enough to afford detached houses. Similarly, the observation in Gwarimpa can be linked to its dense population, which explains why blocks of flats are prevalent in the area.

Figure 1.25 *Residential District by Building Type*



In Jabi, semi-detached houses made up 35.4% of respondents, households, while in Durunmi, one-bedroom apartments accounted for 40.5%. Not surprisingly, Gudu, a low-income district, had the highest proportion of shacks (20%) compared to the other districts, although one-bedroom apartments comprised 55% of respondents' households. The results of the Pearson chi-square test revealed a value of 38.767

with 20 degrees of freedom, which indicated a significant association ($p < .05$). The Cramer's V (ɸ) obtained was 0.07, indicating a trivial association between the districts and building types.

Table 1.3 *Chi-Square Test between Residential Buildings by Residential District*

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	38.767[a]	20	.007
Likelihood Ratio	44.507	20	.001
Linear-by-Linear Association	6.018	1	.014
N of Valid Cases	343		
a. 4 cells (14.0%) have expected count less than 5. The minimum expected count is 2.30.			

The Pearson chi-square test results revealed a chi-square value of 38.767 with 20 degrees of freedom, indicating a significant association between the districts and building types, as evidenced by a p-value less than 0.05. This statistical significance suggests that the observed distribution of building types across different districts is unlikely to have occurred by chance alone. In other words, a discernible pattern in how building types are distributed across districts warrants attention, suggesting that the relationship between these two categorical variables is not random.

However, the strength of this association, as measured by Cramer‘s V (ɸ), was found to be 0.07, indicating a trivial or very weak association. Cramer‘s V, which ranges from 0 to 1, indicates the strength of the relationship between two variables, with values closer to 1 indicating a stronger association. In this case, a value of 0.07 suggests that, while a statistically significant relationship exists between districts and building types, the practical significance is minimal; this means that the pattern, although statistically detectable, is not strong enough to suggest a meaningful or impactful relationship in practical terms. The districts and building types are related, but this relationship is weak, indicating that other factors may play a more substantial role in determining the distribution of building types across districts.

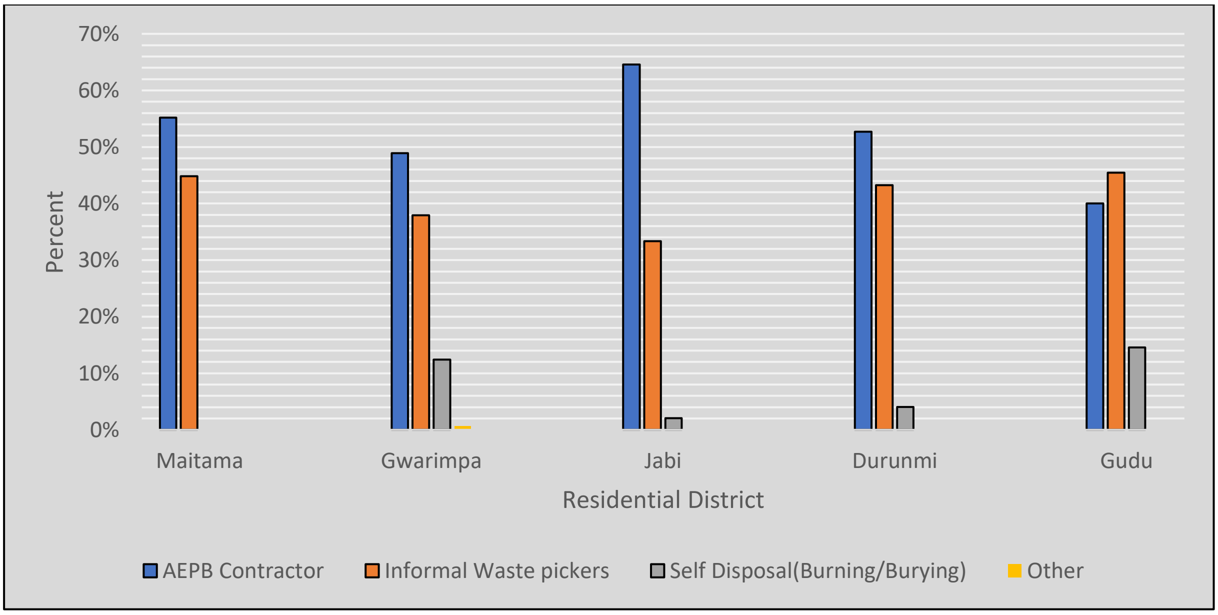
One possible explanation for the modest association is the presence of some lower-income earners within higher-income districts. The spiralling economic and socio-political activities have strained housing and living conditions in the metropolis

(Ogwueleka, 2013), leading to housing shortages (Abubakar, 2014). It is not uncommon to find squatter settlements in construction sites, green areas and unused land in the higher income districts (Abubakar,2014). However, the results suggest that certain types of accommodation were more prevalent in the districts. Although the evidence was trivial, it showed discernible patterns corroborating the classification of districts into income groups based on building types. Despite the correlation, conclusions in this study are drawn with caution and more emphasis on the district.

4.5.1.2. Waste Collection Agent by Residential District

Within the Abuja metropolis, 22 registered contractors under the supervision of AEPB provide door-to-door waste collection services (JICA, 2019). The system is supported indirectly by the activities of informal waste pickers who scavenge for recyclables and other potential items of value. The chart in Figure 4.26 represents the results of the crosstabulation performed to examine the distribution of collection agents among the districts. The indications by respondents in the figure show that most of the districts, Maitama (55.2%), Jabi (64.6%), Gwarinpa (48.9%) and Durunmi (52.7%) rely on AEPB contractors for waste collection except Gudu, which shows that waste collection is predominantly carried out by informal waste pickers (45.5%), with less collection by AEPB contractors (40%). The data also showed that self-disposal is practised most among the respondents in Gudu (14.5%), followed by Gwarinpa (12.4%).

Figure 1.26 *MSW Collection Agent by Residential District*



The Chi-square test results in Table 4.4 examined the relationship between the respondents' residential districts and the responsibility for waste collection and disposal. The test statistic, $\chi^2(12, n = 343) = 17.64$, with 12 degrees of freedom, produced a p-value of 0.127. Since the p-value exceeds the common significance threshold of 0.05, we fail to reject the null hypothesis, indicating no statistically significant association between the residential districts and the entity responsible for waste collection and disposal; this means that the variation in who is responsible for waste collection and disposal depends not on the respondents' residential districts based on the sample data.

Furthermore, the Cramer's V (ϕ) value of 0.127 suggests a weak association between the two variables. Cramer's V measures association strength for nominal data, ranging from 0 (no association) to 1 (perfect association). A value of 0.127 is considered trivial or very weak, reinforcing the conclusion that the residential district has minimal influence on waste collection and disposal responsibility. Therefore, the analysis indicates that factors other than the residential district are likely more influential in determining who is responsible for waste management in this context.

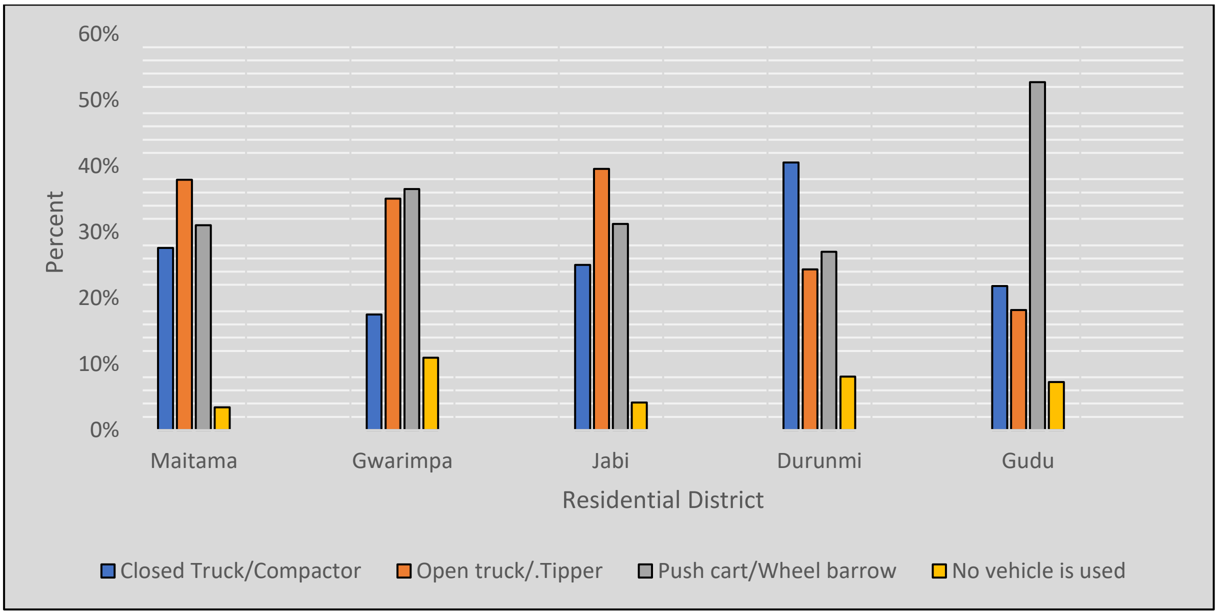
Table 1.4 *Waste Collection Agents and Residential District*

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	17.637[a]	12	.127
Likelihood Ratio	21.068	12	.049
Linear-by-Linear Association	.549	1	.459
N of Valid Cases	343		
a. 4 cells (18.0%) have expected count less than 5. The minimum expected count is 1.27.			

4.5.1.3. Waste Collection Vehicle by Residential District

A crosstabulation analysis was also conducted to compare the distribution of waste collection vehicles among the districts. The results in Figure 4.27 show that the most common waste collection vehicles in Maitama are open trucks/tippers, accounting for 37.9% of the total. Push carts/wheelbarrows come in second at 31.0%, followed by closed trucks/compactors at 27.6%. In Gwarimpa, push carts/wheelbarrows are relied upon more heavily at 36.5%, compared to open trucks/tippers at 35.0% and closed trucks/compactors at 17.5%. Jabi has a mix of closed trucks/compactors (25.0%) and open trucks/tippers (39.6%) as the predominant vehicles, while push carts/wheelbarrows makeup 31.3% of the vehicles used. In Durunmi, the primary vehicles used are closed trucks/compactors (40.5%) and open trucks/tippers (24.3%). Meanwhile, Gudu stands out with most push carts/wheelbarrows at 52.7% but utilises closed trucks/compactors (21.8%) and open trucks/tippers (18.2%). The reporting of wheel carts among the respondents supports the argument that informal waste pickers are actively involved in collection in all the sampled districts.

Figure 1.27 *MSW Collection Vehicles by Residential District*



The Chi-square test results in Table 4.5 indicate a statistically significant association between the respondents' residential districts and the types of waste collection vehicles used. The test statistic, χ^2 (16, n = 343) = 23.45, compares the observed frequencies of waste collection vehicle types across different residential districts to the expected frequencies if there were no association. This test's degree of freedom (df) is 16, corresponding to the number of categories in each variable minus one. Although the Chi-square value of 23.45 suggests some discrepancy between the observed and expected frequencies, the p-value of .102 is greater than the typical threshold of .05, indicating that this association is not statistically significant at the 5% level; this means that the observed differences in waste collection vehicle types across residential districts could be due to random variation rather than an actual underlying pattern.

Despite the initial indication of a significant association from the Chi-square value, the Cramer's V (ϕ) value of .01 reveals that the strength of this association is negligible. In this case, a ϕ value of .01 suggests that even if there were a statistically significant association, the relationship between residential districts and waste collection vehicle types is extremely weak. Therefore, while the Chi-square test provides an initial look into potential associations, the low Cramer's V value emphasises that any relationship between these variables is not practically meaningful, and waste collection vehicle types are likely distributed similarly across different residential districts.

Table 1.5 *Responses to Waste Collection Agent*

Chi-Square Tests			
	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	26.340[a]	12	.010
Likelihood Ratio	25.944	12	.011
Linear-by-Linear Association	.104	1	.747
N of Valid Cases	343		
a. 3 cells (15.0%) have expected count less than 5. The minimum expected count is 2.37.			

4.5.2. Assessment of Waste Management Challenges and Practices by District using Kruskal Wallis Tests

The Kruskal-Wallis H test is a robust nonparametric test that effectively evaluates the existence of significant variances between two or more groups of an independent variable on a continuous or ordinal dependent variable. This test is based on ranking and yields vital perspectives on statistical significance. For this study, the Kruskal Wallis test (see Table 4.6) was performed to compare the mean ranks among the districts on the ordinal variables, daily waste generation (WG), waste collection frequency (WCF), open dumping (DUMP), willingness to pay for waste collection (WTP), participation in environmental sanitation (PSAN), source segregation (SS), recycling (RCY) and frequency of information (INFO). It was hypothesised that there is no significant difference in the mean ranks across the residential districts for all the dependent variables (see Table 3.4).

H_0: There is no difference in mean ranks among the districts for each of the independent variables (WG, WCF, WTP, DUMP, SS, RCY, INFO)

__Table 1.6__ Mean Ranks Comparisons of Key Variables

Ranks				
	Residential District	**N**	**Mean Rank**	**p-value**
WG	Maitama	29	179.05	0.387
	Gwarimpa	137	177.07	
	Jabi	48	186.19	
	Durunmi	74	156.10	
	Gudu	55	164.66	
	Total	343		
WCF	Maitama	29	150.76	0.176
	Gwarimpa	137	170.46	
	Jabi	48	181.56	
	Durunmi	74	160.74	
	Gudu	55	193.85	
	Total	343		
WTP	Maitama	29	152.00	**<.001****
	Gwarimpa	137	194.66	
	Jabi	48	160.96	
	Durunmi	74	135.52	
	Gudu	55	184.82	
	Total	343		
DUMP	Maitama	29	165.26	0.155
	Gwarimpa	137	168.62	
	Jabi	48	156.49	
	Durunmi	74	169.89	
	Gudu	55	200.35	
	Total	343		
SS	Maitama	29	167.36	0.565
	Gwarimpa	137	171.11	
	Jabi	48	164.70	
	Durunmi	74	187.18	
	Gudu	55	162.62	
	Total	343		
RCY	Maitama	29	199.90	0.058
	Gwarimpa	137	154.97	
	Jabi	48	177.21	
	Durunmi	74	175.27	
	Gudu	55	190.76	
	Total	343		
INFO	Maitama	29	164.40	**<.001****
	Gwarimpa	137	179.51	
	Jabi	48	182.42	
	Durunmi	74	133.05	
	Gudu	55	200.60	
	Total	343		

Note: (**) null hypothesis is rejected

The Kruskal-Wallis H Test, a non-parametric method used to compare differences between multiple independent groups, revealed statistically significant differences in mean ranks for both "WTP" (Willingness to Pay) and "INFO" (Information Access) among the five districts. For "WTP," the test statistic was $H(4, n = 343) = 21.25$ with a p-value less than .001, indicating significant differences in mean ranks across the districts. The mean ranks were as follows: Gwarinpa (194.66), Gudu (184.82), Jabi (160.96), Maitama (152), and Durunmi (135.52), showing Gwarinpa with the highest willingness to pay and Durunmi with the lowest. Similarly, for "INFO," the test statistic was $H(4, n = 343) = 19.03$ with a p-value less than .001, again indicating significant differences. The mean ranks for "INFO" were Maitama (164.4), Gwarinpa (179.51), Jabi (182.42), Durunmi (133.05), and Gudu (200.60), showing that Gudu had the highest access to information and Durunmi the lowest. These results suggest that willingness to pay and information access vary significantly among the districts, with distinct patterns in each district‘s mean ranks.

Manual computation of the effect size using the equation put forward by Tomczak and Tomczak (2014) gave Eta squared values of 0.051 for “WTP” and 0.044 for “INFO”, indicating a small effect size for both associations. There was no significant difference in mean ranks for all other variables. There was enough evidence at a 95% confidence level to reject the null hypothesis and assume that the mean ranks among districts for willingness to pay for waste collection services and the frequency of information and communication among districts differed significantly.

Subsequently, post hoc pairwise analysis using Dunn’s (1964) procedure adjusted for Bonferroni correction (0.005) identified statistically significant differences for “WTP” between Durunmi (135.52) and Gwarinpa (194.66), $p < .001$, and for “INFO”, between Durunmi (133.05) and Gudu (200.60), $p < .001$. The evidence suggests that respondents from the Durunmi district were less willing to pay for waste collection services and received less information on waste management than the other districts; this may indicate that frequently receiving information and communication on waste management may influence paying for waste collection services.

4.5.3. Assessment of Interrelationships between Challenges using Spearman’s Correlations

Further exploratory analysis was performed using Spearman’s rank correlation to assess the degree of association between the challenges. A correlation matrix was generated for waste collection frequency (WCF), participation (PSAN), open dumping (OD), waste generation (WG), information and communication (INFO), willingness to pay (WTP), source segregation (SS) and recycling (RCY). The correlation coefficient can range from -1 to +1, translating from -100% to +100%. A positive coefficient indicates a positive correlation, where an increase in one variable corresponds to an increase in the other variable. Conversely, a negative correlation suggests that an increase in one variable leads to a decrease in the other variable. If the score is close to zero, it indicates a very weak or no correlation. However, the coefficient cannot be conclusive unless it is significant at the alpha level ($p<0.05$). Table 4.7 summarises the correlation matrix, showing all statistically significant associations.

Table 1.7 *Correlation Matrix of Variables*

Correlations										
			WG	**WCF**	**WTP**	**INFO**	**DUMP**	**PAT**	**SS**	**RCY**
Spearman‘s rho	**WG**	Correlation Coefficient	1.000	.107	.071	.170	.025	.043	0.068	-0.090
		Sig. (2-tailed)	.	.029	.189	.002	.651	.425	0.210	0.095
	WCF	Correlation Coefficient	.107	1.000	.099	.069	-.113	.085	-0.060	0.015
		Sig. (2-tailed)	.029	.	.068	.205	.017	.117	0.270	0.785
	WTP	Correlation Coefficient	.071	.099	1.000	.069	.149	.018	0.006	-0.008
		Sig. (2-tailed)	.189	.068	.	.204	.009	.736	0.918	0.885
	INFO	Correlation Coefficient	.170	.069	.069	1.000	-.030	.093	-0.001	-0.069
		Sig. (2-tailed)	.002	.205	.204	.	.583	.042	0.979	0.199
	DUMP	Correlation Coefficient	.025	-.113	.149	-.030	1.000	.155	-0.045	0.033
		Sig. (2-tailed)	.651	.017	.009	.583	.	.004	0.404	0.548
	PAT	Correlation Coefficient	.043	.085	.018	.093	.155	1.000	0.021	0.080
		Sig. (2-tailed)	.425	.117	.736	.042	.004	.	0.699	0.138
	SS	Correlation Coefficient	0.068	-0.060	0.006	-0.001	-0.045	0.021	1.000	0.016
		Sig. (2-tailed)	0.210	0.270	0.918	0.979	0.404	0.699		0.774
	RCY	Correlation Coefficient	-0.090	0.015	-0.008	-0.069	0.033	0.080	0.016	1.000
		Sig. (2-tailed)	0.095	0.785	0.885	0.199	0.548	0.138	0.774	
		N	343	343	343	343	343	343	343	343
**. Correlation is significant at the 0.01 level (2-tailed).										

Based on Cohen's (1988) guidelines on correlating correlations, the strength of the statistically significant relationships observed was small in both directions. Table 4.8 summarizes the significant relationships found.

***Table 1.8** Statistically Significant Correlations*

11	Correlation Coefficient	Sig. (2-tailed)
WG * WCF	.107	*p* = .029
INFO * WG	.170	*p* = .002
WCF * DUMP	-.113	*p* = .017
INFO * PAT	.093	*p* = .042
DUMP * `PAT	.155	*p* = .004
DUMP * WTP	.149	*p* = .009

4.5.4. Sociodemographic and Economic Factors Influencing Public Participation in Environmental Sanitation in Abuja

To address **RQ2**, ordinal logistic regression with proportional odds was performed to determine the effect of respondents' sociodemographic characteristics on their participation. A Plum procedure was used since all the predictors were polytomous (Laerd, 2015). The model contained ten predictor variables, including all sociodemographic variables and the constructs for "Awareness" (mA) and "Satisfaction" (mSAT), which could have a possible impact on the dependent variable, participation (PAT). The researcher ensured that the assumptions regarding the variable characteristics were met as the outcome variable was ordinal, and all predictor variables were ordinal, categorical or scaled. Linear regression analysis was conducted to test for multicollinearity assumptions. Table 4.9 presents the results of the test for multicollinearity and shows that all variables were within the acceptable range of tolerance >0.1 and VIF < 10 and met the multicollinearity assumption.

***Table 1.9** Multicollinearity Test*

Coefficients[a]			
Model		Collinearity Statistics	
		Tolerance	VIF
1	Gender	.953	1.049
	Age	.888	1.126
	Education Level	.770	1.299
	Occupation	.850	1.176
	Religion	.906	1.104
	District	.956	1.046

	Household Size	.944	1.060
	Building Type	.925	1.081
	mA	.883	1.132
	mSAT	.865	1.156
a. Dependent Variable: Do you participate in the Environmental Sanitation exercise?			

In Table 4.10, the model fitting data presents the 2-Log likelihood values for both the intercept-only and the full models that incorporate all predictors, providing a basis for evaluating the model‘s fit and predictive accuracy. As per the guidance of Strand, Cadwallader, and Firth (2011), the efficacy of predicting outcomes hinges on the insights gleaned from model-fitting procedures. The analysis reveals that the full model, which includes all relevant predictors, shows a significantly better fit compared to the intercept-only model, as evidenced by the chi-square test of model effects ($\chi^2(68) = 93.260$, $p < .05$). This chi-square statistic indicates that the difference in -2 Log likelihood between the two models is significant, confirming that the inclusion of predictors leads to a considerable improvement in the model‘s ability to explain the observed data. Hence, the model fitting results substantiate that the observed data aligns well with the full model, demonstrating a significant enhancement over the null model, which only includes the intercept, thereby validating the model‘s robustness and predictive capability.

Table 1.10 *Model Fitting Tests*

Model Fitting Information				
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	898.530			
Final	805.270	93.260	68	.023
Link function: Logit.				

The Goodness-of-fit shows the variation of the data that cannot be explained. Hence, it measures how well the observed data corresponds to the fitted model. The Pearson goodness-of-fit test calculates an overall summary of the Pearson residuals to provide a fit measure. On the other hand, the deviance goodness-of-fit statistic measures the difference in fit between the current model and a complete model that perfectly fits the data (Laerd, 2015). Non-significant test results are indicators that the model fits the data well, even when both statistics contrast (Crowson, 2015).

Table 4.11 presents the results of two different chi-square tests used to assess the fit of a statistical model to the observed data. The Pearson chi-square test yielded a value of 1616.196 with 1300 degrees of freedom, indicating a significant result ($p < .001$), which suggests a discrepancy between the observed and expected frequencies, potentially pointing to a poor model fit. In contrast, the Deviance chi-square test, also conducted with 1300 degrees of freedom, produced a value of 805.270 and a p-value of 0.99. The high p-value indicates that the difference between the observed and expected values is not statistically significant, suggesting that the model adequately fits the data. The deviance goodness-of-fit test's non-significant result ($p = 0.99$) implies that the model is a good fit for the observed data, meaning that any differences between the observed data and the model's predictions are likely due to random variation rather than a systematic issue with the model itself.

***Table 1.11** Goodness-of-Fit Tests*

Goodness-of-Fit			
	Chi-Square	df	Sig.
Pearson	1616.196	1300	<.001
Deviance	805.270	1300	0.99
Link function: Logit.			

The proportion of variance in the outcome that the explanatory variables can account for is summarised by the Pseudo R-Square statistics using the three most commonly used measures of R^2, Cox and Snell, Nagelkerke and McFadden (Laerd, 2015). These are Pseudo R-Square values that are treated as rough analogues to the R^2 value in ordinary least squares (OLS) regressiTable 4.12 provides different measures of the variability explained by the model, with Cox and Snell R^2, Nagelkerke R^2, and McFadden R^2 values of 23.8%, 25.7%, and 10.4% respectively. The Nagelkerke R^2, at 25.7%, is used as the primary reference for this study because it is generally considered to provide an approximation closest to the Ordinary Least Squares (OLS) estimate of R^2, which is a standard measure of goodness-of-fit in linear regression models (Smith & McKenna, 2012); this means that the Nagelkerke R^2 is a preferred indicator of how well the model explains the variation in the dependent variable. In this context, the Nagelkerke R^2 value of 25.7% indicates that 25.7% of the variance in participation can be explained by the variables included in the model; this suggests that while the model accounts for a significant portion of the variability in participation, a substantial amount of variance is influenced by other factors not included in the model.

Table 1.12 *Pseudo R-Square Results*

Pseudo R-Square	
Cox and Snell	.238
Nagelkerke	.257
McFadden	.104
Link function: Logit.	

The test results of parallel lines indicate that the model with the assumption of parallel lines (general model) fits significantly better than the null model (without the assumption of parallel lines). Table 4.13 shows the -2 Log Likelihood for the general model was 674.154, while the -2 Log Likelihood for the null model was 805.270 at $\chi^2(204) = 131.116$, $p = 0.99$. These findings suggest that the assumption of parallel lines holds in the ordinal regression model, indicating that the relationship between the predictor variables and the ordinal outcome variable is consistent across different levels of the outcome variable.

Table 1.13 *Test of Parallel Lines*

Test of Parallel Lines				
Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	805.270			
General	674.154	131.116	204	0.99

Table 4.14 presents excerpts of the parameter estimates for the predictor variables with statistically significant outcomes. For the variable "Employment Status," the coefficients were estimated for categories: Unemployed, Self-employed, Civil Servant, Private Sector, and Student (reference category). The residential district's coefficients were estimated for different categories: Maitama, Gwarinpa, Jabi, Durunmi, and Gudu (reference category).

Table 1.14 *Excerpts of Parameter Estimates for Statistically Significant Variables*

Parameter Estimates							
	Estimate	Std. Error	Wald	df	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Unemployed	-1.159	.427	7.355	1	.007	-1.996	-.321
Self-employed	-.784	.417	3.525	1	.060	-1.602	.034
Civil Servant	-1.106	.429	6.637	1	.010	-1.947	-.264
Private Sector	-.706	.481	2.152	1	.142	-1.650	.237
Student	0	.	.	0	.	.	.

Maitama	-1.213	.489	6.158	1	.013	-2.171	-.255
Gwarinpa	-1.113	.349	10.170	1	.001	-1.798	-.429
Jabi	-1.183	.430	7.584	1	.006	-2.026	-.341
Durunmi	-.696	.373	3.477	1	.062	-1.428	.036
Gudu	0	.	.	0	.	.	.

The coefficient estimates indicate the expected change in the log odds of the outcome variable for each unit increase in the corresponding predictor variable. The analysis results revealed several significant findings regarding the likelihood of various respondent groups compared to being a student and residing in different districts. Specifically, unemployed respondents showed a significant result with a chi-square value of $\chi^2(1) = 7.355$ and a p-value of .007, indicating that being unemployed was significantly associated with a decrease in the log-odds of the outcome compared to being a student. Similarly, civil servants had a significant chi-square value of $\chi^2(1) = 6.637$ and a p-value of .010, indicating a decrease in the log odds of the outcome relative to students. Additionally, the place of residence showed significant results: residing in Maitama had a chi-square value of $\chi^2(1) = 6.158$ and a p-value of .013, residing in Gwarinpa had a chi-square value of $\chi^2(1) = 10.170$ and a p-value of .001, and residing in Jabi had a chi-square value of $\chi^2(1) = 7.584$ and a p-value of .006. All these locations were significantly associated with a decrease in the log-odds of the outcome compared to residing in Gudu. These results collectively indicate that employment status and residential location significantly influence the likelihood of the outcome, with certain groups and locations associated with lower log-odds compared to the reference categories.

4.6. Discussion of Study Findings

This section discusses key findings from the quantitative study of 343 respondents from the five sampled districts, Gudu, Durunmi, Gwarinpa, Jabi, and Maitama, which were previously described in this chapter (see section 4.3). Most of the respondents in the study sample were female, accounting for more than half of the participants. Around 45% of the respondents were male, indicating a balanced gender distribution. The participants were categorized based on age, and the median age group ranged between 25 and 39 years old. Most respondents had completed a university-level education, followed by a secondary school-level education. However, a small percentage of participants had no formal education. A significant proportion of the sample population were income earners, with around two-thirds of the participants falling into this category.

As for religious affiliation, most respondents were identified as Christians (62%), followed by Muslims (31%), and a small percentage had no religious affiliation. Gwarimpa had the highest number of respondents (40%), predominantly from the working class, followed by Durunmi (22%) and Gudu (16%). Most households reported having 5-7 occupants (44%), indicating a potentially high volume of waste generation. Preliminary estimates on waste generation and composition revealed by the respondents in this chapter suggest that large quantities of primarily organic waste are generated among the sample, as most respondents (43.1%) estimated generating 2-4 kg of waste weekly made up of mostly food waste.

In terms of housing, self-contained/one-bedroom units and blocks of flats were the most prevalent, reflecting a mix of middle-class and upper-class residents. The socioeconomic classification of the districts indicated a trivial association between the districts and building types. The slight association may be influenced by the online survey method adopted since it is possible to find middle-income dwellers and associated building types within high-income districts. Thus, caution is given to interpretations based on socioeconomic classifications in this chapter. The following subsections give an overview of the quantitative study and highlight the key findings of this study.

4.6.1. Lack of Awareness of WM Practices in Abuja

The lack of awareness was cited in the literature by Kadafa (2017) as one of the challenges facing waste management in Nigeria. Many people, especially in urban areas, may not fully understand the importance of proper waste disposal recycling and the potential impacts of improper waste management on public health and the environment. Researchers widely acknowledge that enhancing public awareness of waste management is crucial to establishing sustainable waste systems and encouraging environmental citizenship among community members.

This study used five waste management concepts centred on the waste hierarchy to assess respondents' knowledge: Recycling, Waste Reduction, Reuse, Waste separation and WtE. Despite the survey respondents‘ relatively high level of education, the findings indicate a lack of awareness of waste management practices among them. This lack of awareness is evident in various aspects of waste management. However, the results indicated that respondents had an average understanding of recycling and reuse, as reflected by median scores of 3.00 for both categories. These findings are consistent with previous reports by Olukanni *et al*. (2016) and Ezeah and Roberts (2012), who also identified a lack of public awareness as a significant challenge to solid waste management in Nigerian cities.

4.6.2. Waste Collection in Abuja

As identified in the literature review, waste collection poses a significant challenge in developing nations like Nigeria (Kadafa, 2017). Most Nigerian cities' primary formal disposal method is landfilling (Ogwueleka, 2013). Several studies have shown that waste collection rates in several Nigerian cities are notably low, with only 25-40% of waste being collected for disposal (Hammed *et al*., 2016; Amusan *et al*., 2018). As highlighted in the literature review in Chapter Two (see section 2.3.1), the collection and disposal of MSW is a duty performed by Nigeria‘s state and local environmental protection agencies. In Abuja, MSW is overseen by AEPB. However, to increase collection efficiency, the government agency registered various contractors under PPP arrangements to collect waste from the municipality within Abuja. These contractors are allocated lots for waste collection and services within the areas. AEPB, on the other hand, focuses on the management of landfills and their collection in the peripheral parts of the FCT (JICA, 2018). Despite the private sector involvement, it was revealed in the review of literature that MSW collection coverage in Abuja is insufficient primarily due to the increasing waste quantities (Abur *et al*., 2014; Amusan *et al*., 2018; Joseph *et al*., 2022).

According to Ayuba *et al*. (2013), waste collection in Abuja is periodically more consistent in some areas than others. However, the authors did not investigate if socioeconomic or other factors influence this. Likewise, there is a possibility that the frequency of collection may depend on who is majorly responsible for waste collection.

The findings from the survey in this study revealed that among the 343 participants, just over half (51%) of the respondents reported private contractors to do waste collection, while 40.2% reported informal waste pickers and few (8.5%) resort to self-disposal. These findings agree with the study by Kadafa (2017), which reported that 43% of waste collection is done by formal and 42% by informal waste collectors. Furthermore, this current study and Kadafa's study found that waste collection is mainly done once a week (47.2% and 45.1%, respectively). Although Ayuba *et al*. (2013) point out that this is the normal agreement with the agency, the high involvement of the informal waste pickers who are not collaborators with the contractors or agency may be due to inadequate collection by the formal waste collectors. Hence, it is possible that some of the collection reported by the participants once a week may be carried out by informal waste pickers. The findings on the responsible agents for waste collection are corroborated by the fact that 63% of the respondents reported that the vehicles used for waste collection are either open trucks or compactors, while approximately 28% reported that collection is done with carts. Formal waste management authorities typically employ compactors and open trucks, while pushcarts are commonly used by the informal waste sector, such as waste pickers, who are also small-scale waste collectors (JICA, 2018; Ogwueleka & Naveen, 2021).

Furthermore, the results showed that 31.6% of waste collection occurs at night, and it has been reported by Ogwueleka and Naveen (2021) that informal waste pickers work during the day and night. Increased activities by the informal sector in Abuja have been reported by Ogwueleka and Naveen (2021). The authors also highlighted the need for an entry point in policy to adopt informal waste pickers into the waste management system. Instead, informal collectors are officially banned from certain districts, and the authorities regularly impounded their carts (Imam *et al*., 2008; Joseph *et al*., 2020). Efforts made by government agencies to restrict the informal collectors from mostly the cosmopolitan parts of the city have been challenging to achieve due to the increasing number of people involved in informal waste collection. The non-statistically significant Kruskal Wallis result in the district-level assessment of waste collection agents tends to strengthen the argument of infiltrating informal waste pickers within the metropolis. Surprisingly, quite a high proportion of respondents in Maitama (45%) reported using the services of informal waste pickers; this differs from the findings of Gajere *et al*. (2019), who surveyed residents in Maitama and reported that only 6% patronise informal waste collectors. There may be several reasons why the two studies have different results. These could include differences in sample size, methodology, and data collection approaches. The size and composition of the sample can significantly affect the relevance of the findings. Also, changes in the timeframe of the studies and differences in waste management practices could impact the differences noticed.

Spearman’s correlation analysis, which explored the interrelationships between the challenges investigated in the study, also revealed some significant findings. A positive correlation was observed between waste collection frequency and waste generation, r (343)= .107, p = .029; this may suggest that those responsible for waste collection, AEPB agents or informal waste pickers, tend to visit those areas where waste generation is higher more frequently. In contrast, a negative association was found between waste collection frequency and open dumping, r (343) = -.113, p = .017. The implication suggests that open dumping increases in areas where waste is less frequently collected. In other words, when waste collection services are infrequent or inadequate, there is a higher likelihood of improper waste disposal in the form of open dumping. The strength of both statistically significant outcomes was small based on interpretations postulated by Cohen (1988); hence, the results may show a trend but are interpreted cautiously. The research results presented in this study shed light on the significant challenges related to waste collection in Abuja. These challenges are further elaborated upon and discussed in the FGDs in Chapter Six.

4.6.3. Willingness to Pay for Waste Services in Abuja

Residential waste management aims to promote a clean environment, enhance the environment's quality, and encourage sustainability. It is expected that citizens pay for waste collection services to ensure that the waste management system is maintained and operated efficiently. However, the literature in Chapter Two (see Section 2.5) reveals that one of the significant challenges in waste management in developing countries is related to the willingness to pay for waste management services (Alabi, 2021; Boateng *et al*., 2019; Ezebilo, 2013). In cities like Abuja, where the waste management system is being privatised, non-payments for the services are bound to impact operation efficiency directly; this is mainly because the service providers rely on revenue from service fees to cover their operational costs and invest in infrastructure improvements. The monthly rate of service charge for waste collection services in Abuja varies based on two classification factors: residential building type and residential district (Adama, 2012). Hence, some districts are charged more than others. Residents are expected to make payments for waste services each month.

Using a 5-point Likert question type, this study revealed that out of the 343 respondents, only about 24% were willing to pay either often or always, while approximately 43% were rarely or never willing to pay for waste services. The remaining respondents (33%) were neutral and reported paying sometimes. These results imply that the service providers are bound to receive irregular payments in Abuja. The relatively low percentage of respondents willing to pay often or always indicates a potential lack of consistent revenue for waste management companies. These results are similar to those reported by Kadafa (2017), whose study on solid waste management practices in Abuja municipalities found that only 20% of the residents were willing to pay for waste management services. Likewise, Boateng *et al*. (2019) assessed the willingness to pay for improved solid waste management services in four major metropolitan cities in Ghana. The study emphasised the importance of sustainable financing mechanisms for waste management and found that willingness-to-pay varied among households based on their income, assets owned, quality of service, occupation, and payment amount.

Further analysis in this study comparing the willingness to pay (WTP) among the sampled districts using the Kruskal-Wallis H Test revealed evidence of a statistically significant difference in mean ranks for WTP among the five districts, $H(4, n = 343) = 21.25$, $p < .001$; this indicates a significant variation in the willingness to pay across the different districts. Subsequent post hoc analysis pinpointed statistically significant differences between Durunmi and Gwarinpa districts ($p < .001$). This significant discrepancy aligns with the findings of Adama and Boateng, suggesting that socioeconomic status or income levels may influence WTP. The trend observed in this study is that districts with varying socioeconomic classifications show differing levels of WTP, supporting the hypothesis that higher-income areas tend to be more willing to pay. This trend underscores the importance of considering socioeconomic factors when evaluating public willingness to contribute financially to community initiatives or services. Another possibility is that the unwillingness to pay observed in Durunmi could result from poor service delivery. However, this study did not reveal any statistically significant result indicating waste collection is more inconsistent in Durunmi district compared to the others, although a significant proportion of respondents in Durunmi (43%) report using the services of informal waste pickers which may be due to inconsistent collection from the formal collectors.

4.6.4. Open dumping in Abuja

Open dumping is one of the most prevalent and widely reported challenges faced in developing countries, with implications for environmental pollution, public health, and climate change (Abdel-shafy & Mansour, 2018; Ferronato & Toretta, 2019). Following recommendations from the literature by Fisher (1993), an indirect question was used to elicit information about open dumping to mitigate social desirability bias from respondents. The results showed that more respondents (38.4%) reported that open dumping rarely or never occurs in their vicinities than those who reported that it often or always occurs (18%). However, around 50% indicated that open dumping is sometimes practised in their areas, which is still a challenge in the Abuja metropolis.

Aderoju *et al*. (2019) conducted a study that supports the findings regarding open dumping as a challenge in Abuja. The study‘s findings align with the observation that despite Abuja‘s aspiration to be a model city with proper waste management practices, open dumping remains a prevalent issue; this highlights the persistence of the problem and the need for further attention and intervention. According to Kadafa (2017), the number of open dumps in Abuja tends to increase as one moves from upper-class to lower-class areas. However, this study did not find a statistically significant difference in the prevalence of open dumping among the socioeconomically classified districts.

The surprising findings revealed that open dumping exhibited a positive correlation with both the willingness to pay for waste services, $r(343) = .149$, $p = .009$, and with participation in waste management activities, $r(343) = .107$, $p = .029$. These results suggest counterintuitive trends that necessitate further investigation. Typically, one would expect that areas with higher rates of open dumping would correspond with a lower willingness to pay for formal waste services, given the presumed lack of financial resources or awareness of the negative impacts of improper waste disposal. However, the positive correlation may indicate that residents in areas with prevalent open dumping, often low-income neighbourhoods where the informal sector handles waste collection due to its affordability, are willing to pay for these more accessible services. Moreover, the positive correlation between open dumping and participation could imply that environmental sanitation efforts and enforcement are more concentrated in areas with higher dumping incidences, driving up participation rates as authorities focus on mitigating this issue. Thus, these unexpected associations suggest that socioeconomic factors and localized enforcement practices significantly influence residents‘ behaviours and attitudes toward waste management, warranting deeper exploration to understand these dynamics fully. A follow-up question on the perceived reasons for open dumping revealed that respondents perceived indiscriminate dumping as primarily due to delayed waste collection, inadequate enforcement, and insufficient awareness. Nonetheless, an expert view of the challenge of open dumping in Abuja is given in the FGD in Chapter Six.

4.6.5. Information and Communication on Waste Issues in Abuja

Some environmental researchers have highlighted the lack of information on waste management issues in developing countries (Ferronato & Torretta, 2019; Viljoen *et al*., 2021). According to Bappayo *et al*. (2018), the media, including radio, TV, and newspapers, play a crucial role in disseminating information and raising public awareness about waste management issues. The findings in this study highlight a significant gap in public communication regarding waste management, with approximately 64% of respondents reporting that they rarely or never receive information on the subject. This lack of information dissemination is concerning, as Ferronato and Torretta (2019) pointed out, particularly in the context of developing countries.

The authors emphasised that the absence of regular, accessible information severely hampers public awareness and education about waste management. Without proper information, communities remain unaware of the critical environmental, social, and health consequences of inadequate waste management practices; this information deficit not only limits the public‘s ability to engage in effective waste management behaviours but also undermines efforts to foster a collective sense of responsibility and action towards sustainable practices. Consequently, improving the frequency and quality of waste management information provided to the public is crucial for enhancing community awareness, fostering better waste management practices, and ultimately mitigating the adverse impacts on the environment and public health. Without access to accurate and reliable information, individuals may not recognize the importance of waste reduction, recycling, and proper disposal (Viljoen *et al*., 2021).

Using Spearman's correlation analysis, this study identified a positive association between receiving information and waste generation, evidenced by a correlation coefficient of $r(343)=0.170$ and a significant p-value of 0.002; this indicates that, among the 343 respondents, those who generate more waste tend to receive more information and communication about waste management. The trend suggests that as waste generation increases, so does the flow of information and communication targeted at those households. This association may confirm that waste collection efforts focus more on households generating higher volumes of waste. Alternatively, it is plausible that the increased burden of waste management on these households drives them to seek more information to actively manage their waste effectively; this dynamic underscores a feedback loop where either targeted communication aims to address higher waste production or the challenges faced by these households spur them to engage more with available information resources.

Furthermore, a statistically significant difference was found when information and communication were compared among the districts, $H(4, n = 343) = 19.03$, $p < .001$. Specifically, post hoc analysis revealed statistically significant differences between Durunmi (133.05) and Gudu (200.60), $p < .001$. Reflecting on the negative attitudes of Durunmi residents towards willingness to pay for waste services from the previous section, the outcome here may suggest that the lack of information and communication among Durunmi residents may be influencing the noncompliance with payment. The investigation is carried forward in the FGD with experts in Chapter Six.

4.6.6. Recycling and Source Segregation in Abuja

Separating materials with economic value from the main waste stream through recycling helps manage MSW; this reduces the amount of waste that must be collected and disposed of, as Matter et al. (2013) noted. Additionally, waste segregation is crucial to maximizing the energy potential of MSW (Yong *et al*.,2019). Different types of waste, such as organic waste, plastics, paper, and metals, can be separated when segregated adequately at the source; this allows for more efficient processing and treatment of specific waste streams. For example, organic waste can be utilized for anaerobic digestion or composting to generate biogas or organic fertilizers, while non-organic waste can be sorted for recycling or energy recovery through WtE technologies (Khan *et al*., 2022).

This study revealed that about 68% rarely or never practice source segregation. Also, approximately 52% of the respondents rarely or never recycle at the household level. This finding suggests that source segregation of waste is not widely adopted among the respondents surveyed. Despite the results indicating that waste is not segregated, recycling is to some extent informally practised through waste pickers whereby recyclables are collected and sorted by informal waste pickers. This is evident in the findings of this study that highlighted the increased activities of informal waste pickers. These informal waste pickers play a significant role in the recycling sector, particularly in developing countries (Ferronato & Toretta, 2019). These individuals collect recyclable materials from mixed waste and sort them for subsequent sale to recycling industries. Their activities contribute to resource recovery, waste reduction, and economic opportunities for marginalized communities (Ogboo and Hussain, 2013).

In Abuja's waste management context, the informal recycling sector fills a crucial gap by diverting recyclable materials from landfill disposal (Ogwueleka & Naveen, 2021). Multiple studies have previously highlighted the lack of waste segregation and recycling practices at the household level in Abuja. Studies conducted by Ogwueleka (2013), Abur *et al*. (2014), Kadafa (2017), Nwosu *et al*. (2016), JICA (2019), and Ike *et al*. (2018) consistently reveal the minimal adoption of waste management practices in Abuja households. These studies,, compared tothe findings of this currentstudys, indicate the prevalenceof the challenge in the capital city. Despite the lack of formal waste segregation at the source, the increasing involvement of waste pickers highlights the potential for recycling and resource recovery. However, public knowledge of segregation and recycling needs to be enhanced to maximise the potential benefits.

4.6.7. Sociodemographic and Economic Factors Influencing Public Participation in Environmental Sanitation in Abuja

Public participation plays a crucial role in the success of environmental sanitation initiatives, including the environmental sanitation exercise in Nigeria. The exercise, a crucial government intervention, aims to improve sanitation and raise public awareness of environmental issues. The National Environmental Sanitation Policy of 2005 provides a framework for coordinating the efforts of all stakeholders involved in environmental sanitation and clarifies their roles and responsibilities. The policy recognizes the importance of public participation in achieving its objectives. It emphasises the need to enhance the capacity of institutions and agencies involved in sanitation programs to effectively engage with the public (Danbaba *et al*., 2016).

The introduction of environmental sanitation programs in many states of Nigeria has not resolved the paradoxical nature of environmental sanitation in the cities, and despite the implementation of these programs, the sight of cityscapes across the country continues to reflect a lack of citizen participation in the process (Olowoporopku, 2017). The exercise is predominantly governed by various environmental legislations and compliance monitoring mechanisms, without giving due consideration to the active involvement of citizens.

This study showed that over half (52%) of the 343 respondents reported participating rarely or never in the Environmental Sanitation exercise, while only 9.6% reported always or often participating. However, a considerable portion of respondents (38.2%) reported participating sometimes, suggesting intermittent engagement in the exercise. Furthermore, respondents‘ opinions on the effectiveness of environmental sanitation showed that approximately 67% disagreed or strongly disagreed that environmental sanitation is an effective waste management strategy in Abuja. This negative response to waste management activities was also reported in a study by Danbaba *et al*. (2016) that assessed the implementation of the policy in Abuja. In their study, 59% of the respondents reported not participating in the monthly sanitation exercise, and 79% stated that the policy did not fulfil its objective. These consistent findings across both studies emphasise the need to address the challenges and shortcomings of the Environmental Sanitation exercise in Abuja. The low participation rates and negative perceptions suggest a disconnect between the policy implementation and the expectations and needs of the residents (Danbaba *et al*., 2016).

To address the second research question (**RQ2**) in this study, the researcher developed an ordinal logistic model using a PLUM procedure to determine if sociodemographic and economic factors influence public participation in sanitation exercise. The outcome variable was responses to participation in the environmental sanitation exercise. The predictor variables included gender, age, education level, occupation, religion, residential district, household size and building type. The other two variables were constructs for awareness and level of satisfaction, which improved the model fit; this was confirmed by the test of parallel lines, which indicated that the relationship between the predictor variables and the ordinal outcome variable was consistent across different levels of the outcome variable.

The study revealed statistically significant relationships between respondents' employment level and their residential district, particularly in their participation in a sanitation exercise. The results demonstrated that the odds of being unemployed significantly affected the log odds of participation, as indicated by the chi-square value of $\chi^2(1) = 7.355$ and a p-value of .007. This finding suggests that unemployed respondents were significantly less likely to participate in the sanitation exercise than students. Similarly, civil servants exhibited a significant relationship with participation, as shown by a chi-square value of $\chi^2(1) = 6.637$ and a p-value of .010, indicating a decreased likelihood of participating in the sanitation exercise compared to students.

These outcomes suggest a trend where employment status significantly influences participation in community activities, with unemployed individuals and civil servants being less engaged in the sanitation exercise than students, holding all other variables constant. This trend highlights the potential need for targeted strategies to encourage participation among employment groups to enhance community sanitation efforts. Hence, unemployed individuals and civil servants were less likely to engage in sanitation exercises than students. Possible explanations for these findings could include differences in available time, financial constraints, or varying levels of awareness and motivation among different employment groups. Considering the exercise is held during the weekend, unemployed individuals may face challenges in allocating time and resources to participate in sanitation exercises because the weekend may be an opportunity for them to leave their homes in search of ways to make income. Similarly, civil servants who have worked through the week may see it as a day of rest or to attend to other commitments and may perceive sanitation exercises as less relevant to their professional roles.

Regarding the residential location, respondents residing in Maitama ($\chi^2(1) = 6.158$, $p = .013$), Gwarinpa ($\chi^2(1) = 10.170$, $p = .001$), and Jabi ($\chi^2 = 7.584$, $p = .006$) were found to have a significant impact on the log-odds of the outcome; this suggests that residing in these areas was associated with a lower likelihood of being in a higher category of participating in the sanitation exercise as compared to residing in Gudu, given that all the other variables in the model are held constant. These findings suggest differences in sanitation exercise participation based on residential location within Abuja. It implies that residents in certain areas may face barriers or constraints that hinder their engagement in sanitation activities more than in other areas. Some researchers have identified how factors such as socioeconomic status, access to sanitation facilities, cultural norms, and community resources may influence participation in waste management (Amasuomo *et al*., 2015; Babayemi & Dauda, 2010; Jereme *et al*., 2021; Oyelakin *et al*., 2022).

For instance, Maitama is classified as a high-income residential area in Abuja, and residents may have better access to sanitation infrastructure and services than in other areas (Abubakar, 2017); this could result in a lower likelihood of active participation in sanitation exercises, as the need for improvement or engagement may be perceived as relatively low; this means that lower-income areas may lack sanitation infrastructure resulting in indiscriminate disposal and thereby requiring more enforcement. However, while residents in high-income areas may have better access to sanitation infrastructure, their level of active participation may still vary based on individual attitudes and perceptions (Oyelakin *et al*., 2022). Similarly, Gwarinpa is a relatively large residential area that has experienced rapid urbanisation (Abubakar, 2014). The challenges associated with managing waste in densely populated areas, coupled with limited waste management infrastructure and services, may contribute to the lower likelihood of active participation in sanitation exercises.

Public participation is vital for creating a sense of ownership and responsibility among individuals and communities, and it empowers them to take an active role in waste management, sanitation, and environmental protection. By engaging the public in environmental sanitation exercises and other initiatives, the government can foster a culture of environmental consciousness and encourage behavioural change towards sustainable practices. Overall, the factors identified in this study can inform targeted interventions and strategies to enhance engagement. Tailored awareness campaigns, flexible scheduling of sanitation exercises, and the inclusion of diverse stakeholders, including civil servants and unemployed individuals, could help increase their participation rates.

4.7. Chapter Summary

The purpose of the quantitative survey was to explore the current state of waste management and examine the challenges and practices among residents in Abuja. Three hundred forty-three valid survey responses were analysed from five major districts within the city, Gudu, Durunmi, Gearinpa, Jabi and Maitama, which were selected based on their representativeness of the different socioeconomic groups. The results showed that Abuja faces various challenges in its waste management system. Issues were identified with waste collection, open dumping, willingness to pay for waste services, lack of awareness, and poor recycling and segregation practices. Furthermore, the study highlighted poor attitudes towards participating in the environmental sanitation exercise and determined that participation may be influenced by employment and socioeconomic status. These results provide the basis for the FGD presented in Chapter Six. The next chapter presents the results of the waste composition study, which is part of the quantitative phase of this research.

Chapter 5: Current Trends in Waste Generation and Composition in Abuja

5.1. Introduction

Waste generation is primarily a function of people's consumption patterns and thus is based on their socioeconomic characteristics (Kaza *et al*., 2018). Abuja's rapid urbanisation and population growth have led to increased waste generation. Rapid economic development, coupled with changing lifestyles and consumption patterns, has contributed to the rising waste generation and changes in composition in Abuja (Kadafa, 2017; Ogwueleka, 2013). This implies that as people's incomes increase and consumerism grows, so does the amount of waste generated; this is particularly evident in residential areas, where the increasing number of households and the adoption of modern conveniences have led to a rise in waste quantities. In addition, the rise in waste production has been influenced by the commercial and institutional sectors.

As Abuja expands as a major business centre, more commercial entities have emerged, contributing to the increase in waste generation (Abubakar, 2014; Adama, 2012). Similarly, the composition of waste in Abuja has also changed due to these factors. With the rise of modernisation and the adoption of new technologies, there has been a shift in the types of waste produced, and the increased consumption of packaged goods has resulted in a higher proportion of plastic and paper waste (Njoku *et al*., 2014).

This chapter presents the results of the fieldwork carried out for this research in October 2021 to determine the trends in waste generation and composition in the Abuja Metropolis. Chapter One of this study explains that a comprehensive understanding of the waste streams is vital to guide decision-makers when considering waste treatment and technology options (Khan *et al*., 2022). Additionally, understanding what materials are in the waste stream can help identify opportunities for reuse and recycling, reducing the burden on landfills and helping preserve natural resources. Moreover, a general understanding from a socioeconomic view is vital for predicting trends and improving collection planning and strategies (Ogwueleka, 2013).

Regrettably, numerous developing countries lack the essential statistical data required, and even in cases where such data exists, it is often inconsistent due to multiple unverifiable sources and reliance on assumptions rather than scientific measurements (Miezah *et al*., 2015). For example, a study in 2013 by Ogwueleka on household waste generation and composition in Abuja reported an average per capita of 0.634kg/capita/day, while a more recent study on ISWM systems in Abuja in 2018 by JICA reported an average per capita of 0.50kg/capita/day. Considering the increase in development, increased economic activities and changes in population density in Abuja between both periods, it is expected that the daily per capita would more likely increase than decrease (Kaza *et al*., 2018; Masebinu *et al*., 2017). Such misleading data can create confusion and doubt in investors' minds seeking to engage in waste management services or business opportunities.

Furthermore, a recent study by Seidu *et al*. (2021) examined waste composition in the Gosa dumpsite in Abuja. Although the findings may prove helpful, they do not give an accurate picture of the waste composition generated from the source, given the city's level of activities by informal waste pickers. Hence, this study seeks to enhance comprehension of Abuja's waste quantities and composition. The research questions guiding this chapter are focused on understanding waste generation patterns and differences among socioeconomic groups in Abuja. The specific research questions are as follows:

RQ3: What is the current estimated per capita waste generation and the daily amount of waste generated in Abuja?

RQ4: Does socioeconomic status influence waste generation and composition in Abuja?

The chapter analyses primary waste data collected during the study to address these research questions. The following section highlights the distribution of the waste data and its implications for statistical analysis.

5.2. Distribution of Waste Data

Chapter Three highlighted that the waste data collected in the study exhibited a non-normal distribution, which can be attributed to the heterogeneous nature of waste components (Noufal *et al*., 2020). In this research, the choice of statistical methods employed by the researcher considered the nature of the data, the sample size, and other relevant assumptions. Following the argument put forward by Pallant (2020) that with sample sizes larger than 30, the Central Limit Theorem can often mitigate the impact of non-normality on inferential statistics, the decision on the statistical method of choice in this research is made with consideration of meeting the assumption of homogeneity. Homogeneity of variance was assessed using Levene’s test to determine whether the variances of waste generation or composition from the different districts were approximately equal.

When employing Levene’s tests, a statistically significance value (<.05) indicates that the variances of waste components for the districts are not equal and, therefore, violate the assumption of homogeneity of variance; hence, non-parametric tests that do not assume equal variances (Pallant, 2020). On the other hand, if the p-value is not statistically significant (>.05), there is evidence that the observed variances of the waste components for the districts are equal, and the assumption of homogeneity of variance e has been met. In this case, parametric procedures can still be applied in cases where normality is not met (Ghasemi & Zahediasl, 2012; Pallant, 2020). The Levene’s test results for equality of variance in this study are presented in the inferential analysis section of this chapter.

5.3. Sociodemographic Characteristics of the Study Area

Because of time constraints for this research, only three out of the five districts were surveyed: Gudu, Gwarinpa, and Maitama. These districts correspond to low-income, middle-income, and high-income areas based on the predominant building characteristics in each district (see Table 3.4 in Chapter Three). The door-to-door sampling method was more effective in validating the socioeconomic classification of households in the study area. This approach allowed the researcher to observe the physical conditions of the households, such as housing quality, living standards, and neighbourhood characteristics. These visual observations supported the socioeconomic classification process and enhanced the accuracy of the findings.

5.4. Results of MSW Waste Generation Analysis

The measurement or estimation of the amount of MSW generated can vary depending on the stage at which it is assessed, such as at the source of generation, during collection, or at the disposal site. However, accurately measuring waste generation volumes can be challenging, especially in developing countries where direct measurement is not always feasible (Liu *et al*., 2019). In this study, the estimates for MSW are measured at the point of generation, specifically within households. Measuring the quantity of waste at the generation source provided a direct and accurate assessment of the waste generated by individual households (Miezah *et al*., 2015). This sampling method allowed for data collection on waste generation patterns and quantities without the potential loss of waste during transportation or due to the high activities of waste pickers highlighted in Chapter Four.

By measuring the waste at the point of generation, the study mitigates the potential biases or inaccuracies that may arise when estimating waste generation based on other stages or locations. Waste can be lost or improperly accounted for during collection or transportation, leading to underestimation or misrepresentation of the generated waste. Additionally, the involvement of waste pickers or scavengers in the collection process can further affect the accuracy of waste estimates. The figures presented in Table 5.1 show that 24 households were sampled, resulting in 120 waste samples over five consecutive days. The collected waste samples amounted to a total of 498kg of MSW.

Table 1.15 *Districts and Waste Generated During Survey*

Income Classification	Districts Sampled	Total no. of households	Total Household Occupants (Persons)	No. of survey days	Total Samples	Total weight of MSW (KG)
Low-Income	Gudu,	8	52	5	40	133.7
Middle-Income	Gwarinpa	8	56	5	40	188.6
High-Income	Maitama	8	45	5	40	175.7
Total		24	153			

Chapter Two discusses the impact of economic growth and urbanisation on waste generation and management in Abuja. Adama (2012) researched the environmental challenges associated with urbanisation in the Abuja Municipal Area Council. The study highlighted how the rapid urbanisation process in Abuja has resulted in increased waste generation, inadequate waste management infrastructure, and environmental degradation; this underscores the need for effective waste management strategies to cope with the growing demands of urbanisation.

This study found the highest MSW generated in the Gwarinpa district, amounting to 188.6kg. Maitama and Gudu districts generated 175.7kg and 133.7kg of MSW, respectively. This disparity in waste generation among the districts can be attributed to various factors, including the total number of household occupants. The results may be due to Gwarinpa having the highest number of household occupants recorded at 59. The larger population in this district likely contributes to a higher quantity of waste generated. With more residents residing in Gwarinpa, there is likely an increased level of consumption, resulting in greater waste generation.

5.4.1. Estimation of Per Capita and Daily Waste Generation in Abuja

Accurate waste generation measurement and estimation are essential for waste management planning and decision-making. Per capita waste generation is a commonly used indicator for evaluating and comparing waste generation intensity among cities or countries (Kawai & Tasaki, 2015). To address RQ3, the MSW generation per capita for this study was estimated using Formula 1 (refer to section 3.3.1.7.2) proposed by Miezah *et al*. (2015). It was measured by sampling and weighing household waste and counting the number of occupants in households multiplied by the number of survey days. The total MSW samples collected from the study areas was 498kg, involving 24 households and 153 residents. The per capita generation for each day during the five-day study period (Tuesday – Saturday) was measured as shown in Table 5.2.

The average daily per capita generation derived for each socioeconomic group in this study was 0.78kg/capita/day, 0.674kg/capita/day, and 0.514kg/capita/day for Maitama, Gwarinpa and Gudu, respectively. Following the socioeconomic classification in this study, the results imply that the high-income households had a higher per capita waste generation than the others; this concurs with previous literature (see Section 2.7) that socioeconomic levels predict waste generation and high-income households generally generate more MSW (Kala & Bolia, 2020; Ogwueleka, 2013; Hoornweg & Bhada-Tata, 2016).

The analysis of waste generation rates in Table 5.2 revealed an interesting pattern where waste generation increases towards the weekend, specifically on Day 4 (Friday) and Day 5 (Saturday). This trend was evident in the Gwarinpa and Maitama districts as well as the middle-income and high-income districts. The increase in waste generation during the weekend can be attributed to residents spending more time at home during these days. As individuals have more leisure time and engage in various activities, such as hosting gatherings, cooking meals, and undertaking household chores, consumption rates tend to rise, increasing waste generation (Dikole & Letshwenyo, 2020). On weekends, people often have more free time to engage in social activities, including inviting friends or family for meals or entertainment. These social gatherings generate additional waste, including packaging materials, food scraps, and disposable items (Bandara *et al*., 2007).

The observed pattern of increased waste generation on Fridays and Saturdays aligns with the typical behaviour of residents when they have more time to spend at home and engage in various activities. The study by Letshwenyo and Kgetseyamore (2020) on waste composition in Botswana revealed a similar trend of waste increase during weekends. Likewise, the study also observed that this trend was only evident in middle and high-income areas. The explanation proposed by both studies suggests that individuals in low-income areas may be engaged in work activities during weekends, leading to less waste generation in their households, highlighting the influence of income and employment on waste generation patterns. Individuals in low-income areas may have different work schedules or be engaged in informal or labour-intensive occupations that limit their time at home during weekends. Consequently, the reduced presence at home may result in lower waste generation during weekends.

The average daily per capita waste generation rate was 0.66kg/capita/day, an increase from 0.634kg/capita/day reported by Ogwueleka (2013). According to Kaza et al. (2018), per capita waste generation increases as countries develop. The authors noted that by 2050, per capita waste generation in low—and middle-income countries is expected to increase by 40%. Based on Abuja's current population (2,376,500), this study estimated that the city generates approximately 1,568 tonnes of MSW daily. This estimate represents a significant increase from the 492 tonnes reported by Ogwueleka (2013) and the range of 828 to 1035 tonnes estimated by Abur *et al*. (2014).

The revised estimate of 1,568 tonnes of MSW daily underscores the growing waste generation in Abuja. It emphasises the need for effective waste management strategies to handle the increasing volume of waste. The higher estimate compared to previous studies could be attributed to factors such as population growth, urbanisation, and changes in consumption patterns over time.

Table 1.16 *Daily Per Capita Waste Generation During Study Period*

	Daily per capita waste generation (kg)		
	Gudu	**Gwarinpa**	**Maitama**
Day 1	0.382	0.644	0.752
Day 2	0.467	0.651	0.716
Day 3	0.597	0.691	0.732
Day 4	0.587	0.688	0.761
Day 5	0.539	0.694	0.942
Overall Average	**0.514**	**0.674**	**0.78**

One explanation for this increase in MSW generation could be the rapid urbanisation rates resulting in rapid population growth in Abuja. Economic growth and increased minimum wages, resulting in a change in consumption patterns (Ogwueleka, 2013), can also explain this. Kaza *et al*. (2018) also project that per capita waste generation in developing countries is expected to increase by 40% or more by 2050.

5.5. Results of MSW Waste Composition Analysis

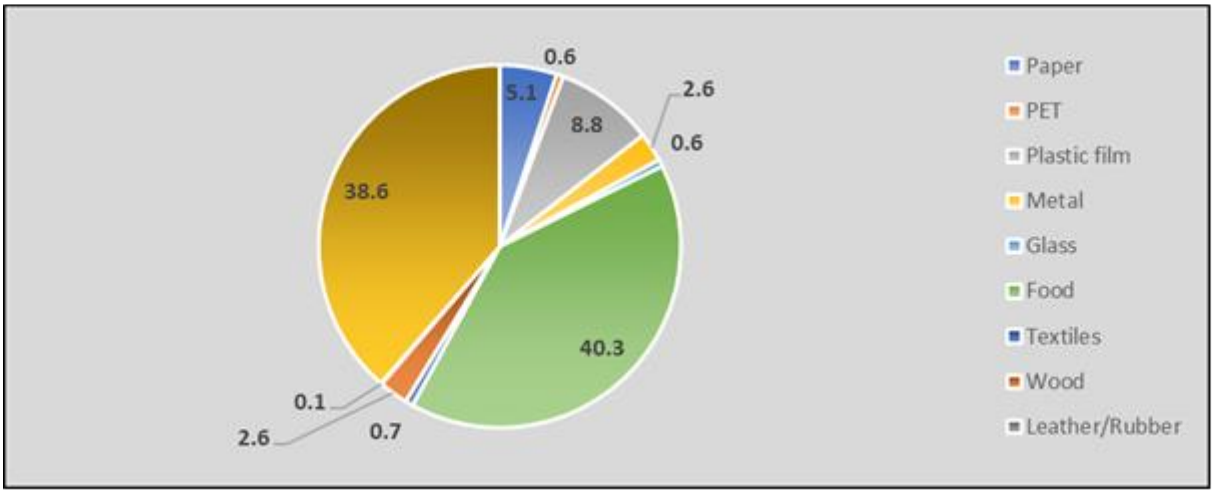
Waste composition is the distribution of different components or materials within the waste stream, expressed as a percentage of the total mass generated. It involves the physical separation, weighing, and categorising MSW into various categories or fractions (Ezeah & Roberts, 2012). Waste management stakeholders can determine the feasibility and effectiveness of different waste treatment and disposal options by assessing the composition. In the context of WtE, the different technologies have specific requirements for the types and proportions of waste components as feedstock (Khan *et al*., 2022). For example, some technologies may be more suitable for processing organic waste, while others may better handle specific types of plastics or other energy-rich materials. Therefore, waste composition analysis is vital to any WtE viability study.

As pointed out in Chapter Two (refer to section 2.7), MSW composition can be influenced by factors such as income, seasonal variation, consumption patterns, waste disposal habits and even the level of activity of waste pickers. Moreover, the organic fraction is primarily influenced by income level (Adeleke et al., 2021). Hence, a socioeconomic perspective of waste composition can be useful in predicting trends in waste composition. The following subsections give a breakdown of the composition results for each district.

5.5.1. MSW Composition in Gudu District

Figure 5.1 visually represents the waste composition in the Gudu district of Abuja. As depicted in the figure, food waste constitutes the highest fraction, accounting for 40.3% of the waste generated in the district. Additionally, waste categorised as "others" represents 38.6% of the waste composition.

Figure 1.28 *Waste Composition in Gudu District (low-income)*

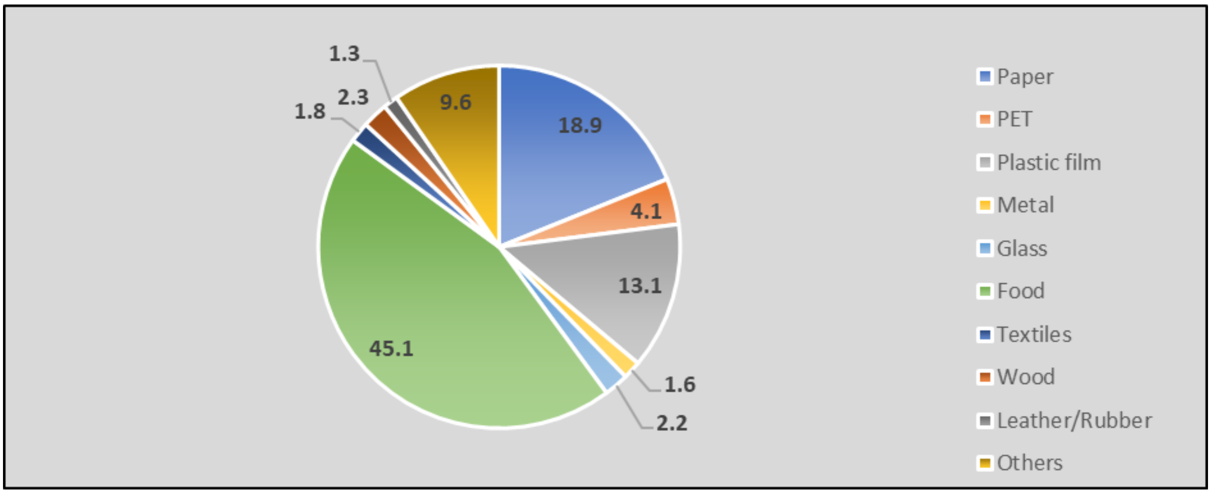


Plastic film was also a critical component of the waste composition within the category, with 8.8%, while 5.1% of the composition was paper. Other components in the waste stream included metal (2.6%), wood (2.6%) and equal fractions (0.6%) of glass and metal. Leather (0.1%) was the least present in the waste stream.

5.5.2. MSW Composition in Gwarinpa District

Gwarinpa, a developed district in Abuja Phase 3, is characterised by primarily blocks of apartments, which make it easier to access and recruit household participants. Looking at the data presented in Figure 5.3, the organic waste fraction was again the highest (45.1%), while paper (18.9%) was the second most predominant component, followed by plastic film (13.1%), and "others" represented 9.6% of the waste stream.

Figure 1.29 *Waste Composition in Gwarinpa District (middle-income)*

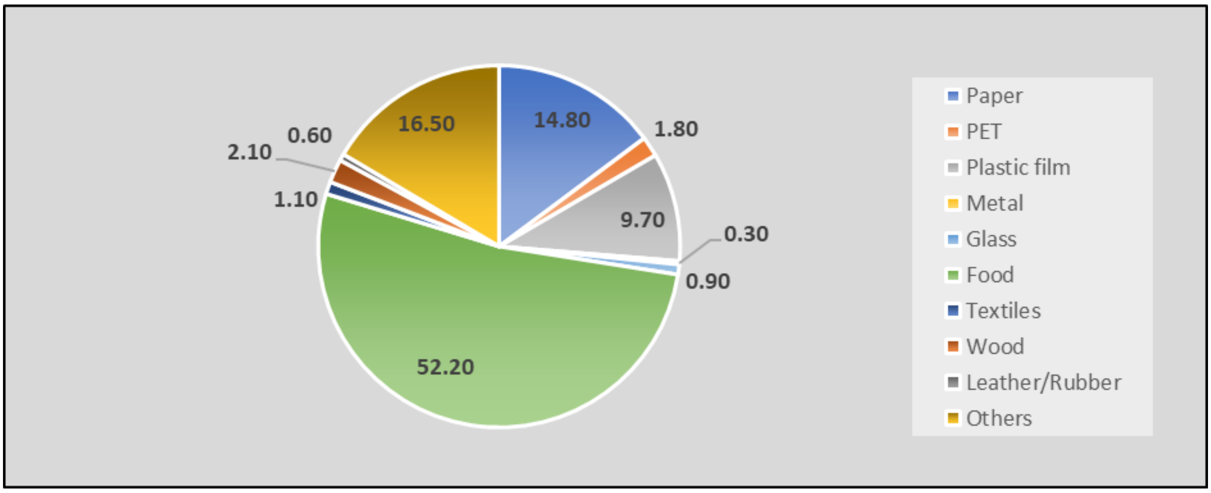


As noted earlier, Gudu district is characterised by its high population density, predominantly comprising a working-class demographic, including a substantial number of civil servants. Additionally, the district features a significant level of commercial activity. Commercial activities, such as printing and paperwork, can increase the production of paper waste, leading to a higher percentage of paper in the waste composition. Similarly, in a waste composition study within the Makurdi environs, Ekwule *et al*. (2020) reported the highest percentage of paper in the waste composition among the middle-income areas. They attributed it to factors such as a higher level of education, greater access to printed materials, and increased consumption of packaged goods that utilise paper-based packaging. A breakdown of the remaining vital components included PET (4.1%), wood (2.3%), Glass (2.2%), and Textiles (1.8%), while metal and leather/rubber fractions were 1.6% and 1.3%, respectively.

5.5.3. MSW Composition in Maitama District

Like most high-income areas, Maitama is a low-density neighbourhood characterised mainly by large, detached housing units. These spacious and affluent residential properties contribute to the overall character and ambience.

Figure 1.30 *Waste Composition in Maitama District (high-income)*



The results for this district in Figure 5.3 show that the food component accounted for more than half of the entire sample (52.2%), followed by "others" (16.5%). The high fraction of organic waste observed in the high-income area of Abuja is consistent with the findings of Ekwule *et al*. (2020) in their waste composition study conducted in the Makurdi environs. Despite being conducted in different locations, both studies reveal a similar pattern of organic waste dominance in high-income neighbourhoods. The MSW comprises paper and plastic film with 14.8% and 9.7% representation, respectively. The remaining parts of the waste sample included wood (2.1%), PET (1.8%), textiles (1.10%), Glass (0.9%), leather/rubber fractions (0.6%) and the least fraction was metals with 0.3%.

Table 1.17 *Summary of Waste Composition by District*

Waste Fractions	Gudu (Low-income)	Gwarinpa (Middle-income)	Maitama (High-income)	Mean
Paper	5.1	18.9	14.8	12.93
PET	0.6	4.1	1.8	2.17
Plastic film	8.8	13.1	9.7	10.53
Metal	2.6	1.6	0.3	1.50
Glass	0.6	2.2	0.9	1.23
Food	37.3	45.1	52.2	45.87
Textiles	0.7	1.8	1.1	1.20
Wood	2.6	2.3	2.1	2.33

Leather/Rubber	0.1	1.3	0.6	0.67
Others	41.6	9.6	16.5	22.57
Total	***100***	***100***	***100***	***100***

5.6. Inferential Analysis of Waste Data

As previously stated in Chapter Three (see Section 3.3.1.8.4), the primary objective of inferential statistics is to make predictions and draw conclusions about specific parameters of the parent population based on the information obtained from the sample data. The inferential analysis in this study aimed to investigate if there was any statistically significant difference in waste generation and composition among the socioeconomically classified districts in Abuja. By analysing the data from a subset of the population (the sample), the study sought to conclude waste generation and composition trends in the entire population of Abuja. This information is crucial for waste management planning, as it helps in understanding the composition of the waste stream and determining the appropriate waste management strategies and the technologies needed to handle the different waste materials effectively.

Planning waste collection based on providing waste feedstock for WtE technologies is also crucial. The analysis used statistical techniques to test hypotheses and assess the significance of observed waste generation and composition differences among the socioeconomically classified districts. IBM SPSS Statistics 27.0 statistical software was employed for the data analysis and was used to conduct ANOVA and Kruskal-Wallis tests to compare the distribution of waste generation and composition among the socioeconomic groups. Within this section, the names of the districts are replaced by their socioeconomic classifications (see Table 5.1).

5.6.1. Effects of Socioeconomic Status on Waste Generation

The effects of socioeconomic and demographic factors on waste generation and composition have been highlighted in various studies (Adeleke *et al*., 2021; Ogwueleka, 2013; Ozcan *et al.*, 2016; Trang *et al*., 2017). A One-Way ANOVA test was used to determine if there was a statistically significant difference in waste generation between the socioeconomically classified districts. As noted in the literature in Chapter Two (see section 2.7), Ogwueleka (2013) explains that there can be a positive or negative relationship between waste generation and income depending on the city or country; hence, it was necessary to understand the direction of the relationship in this study. The descriptive statistics (Table 5.4) show that the high-income group had the highest average of daily per capita waste (M = 0.780, *SD* = 0.092), followed by the middle-income (M = 0.674, *SD* = 0.024) and the low-income group (M = 0.514, *SD* = 0.090).

***Table 1.18** Descriptive Statistics of Waste Generation by Income Group*

Descriptives								
kg/capita/day								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
low income	5	.51440	.090104	.040296	.40252	.62628	.382	.597
middle income	5	.67360	.024048	.010755	.64374	.70346	.644	.694
high income	5	.78060	.091906	.041102	.66648	.89472	.716	.942
Total	15	.65620	.133096	.034365	.58249	.72991	.382	.942

Since the per capita waste generation was derived from the original composition dataset, non-normality was still assumed. Hence, the decision to apply parametric or non-parametric tests depended on meeting the homogeneity assumption. A requirement for employing the ANOVA test is to meet the assumption of homogeneity of variance. In this case, the Null hypothesis H_0 is that the variance in per capita waste generation is equal across all socioeconomic groups if $p < .05$**.** Table 5.5 shows the results of Levene's tests of the homogeneity of group variances, indicating that the assumption of homogeneity was met ($p > .05$); therefore, the null hypothesis cannot be rejected, and assume that there is no significant difference in the variance of waste generation in the socioeconomic groups.

***Table 1.19** Homogeneity of Variance of Waste Generation*

Tests of Homogeneity of Variances					
		Levene Statistic	**df1**	**df2**	**Sig.**
kg/capita/day	Based on Mean	2.319	2	12	.141
	Based on Median	.945	2	12	.416
	Based on Median and with adjusted df	.945	2	7.943	.429

	Based on trimmed mean	1.928	2	12	.188

Since the requirement for homogeneity of variance has been met, the ANOVA test results in Table 5.6 can be considered robust. The one-way ANOVA test results in Table 5.6 demonstrate a significant difference in per capita waste generation across different socioeconomic groups, as indicated by an F-value of 15.699 with degrees of freedom (2,12) and a p-value of .000. This extremely low p-value (less than .001) suggests that the observed differences in waste generation between the groups are highly unlikely to have occurred by chance, confirming that socioeconomic status significantly influences per capita waste generation.

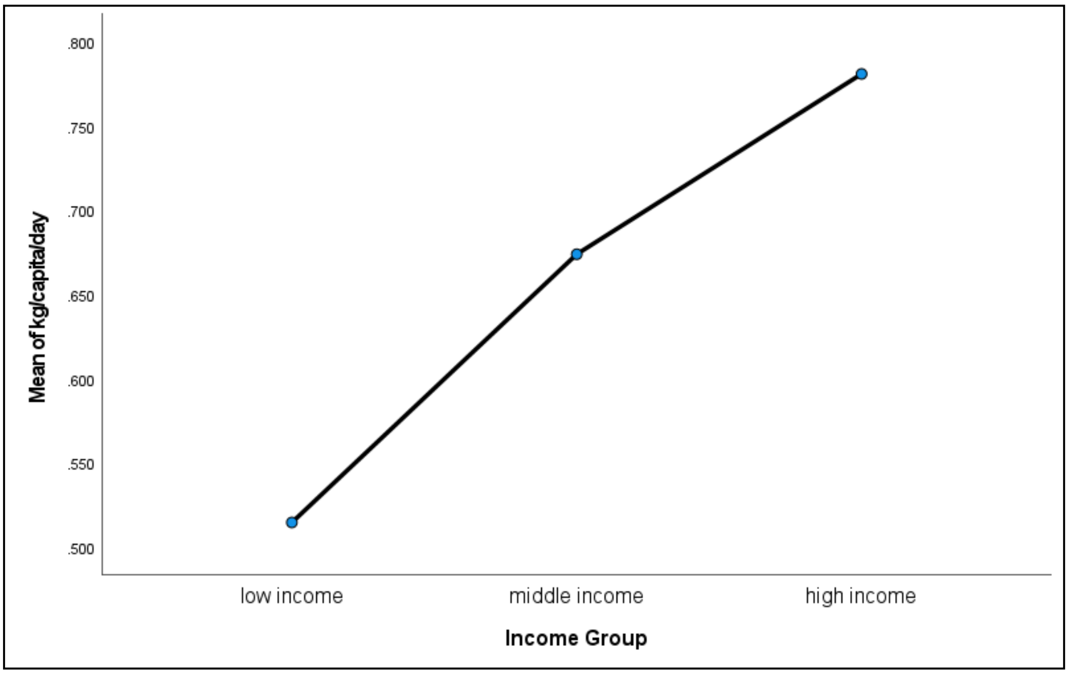
Furthermore, the calculated effect size (Eta squared) was 0.7, considered large. This substantial effect size indicates that a considerable proportion of the variance in waste generation can be attributed to differences in socioeconomic status. In practical terms, socioeconomic factors dominate in determining waste generation patterns, with higher socioeconomic groups likely generating more waste per capita than lower socioeconomic groups. This trend highlights the critical need for targeted waste management policies that consider socioeconomic disparities to address waste generation and effectively promote sustainability.

Table 1.20 *One-way ANOVA Per Capita Waste by Income Group*

ANOVA					
kg/capita/day					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.179	2	.090	15.699	.000
Within Groups	.069	12	.006		
Total	.248	14			

The positive correlation can also be seen in the means plot in Figure 5.4, where the means of per capita waste generation increase as income levels increase.

Figure 1.31 *Distribution of Mean Per Capita by Income Level*



A Tukey post hoc test in Table 5.7 reveals distinct municipal solid waste (MSW) generation patterns across different income groups. Specifically, the test indicates that low-income groups generate significantly less MSW per capita than middle-income and high-income groups, with p-values of .015 and less than .001, respectively, underscoring a statistically significant difference. This trend suggests that as income increases from low to middle and high, there is a corresponding increase in waste generation. However, the analysis also highlights that the difference in per capita MSW generation between high-income and middle-income groups is not statistically significant (p = .105); this implies that the increase in income does not result in a substantial rise in waste generation beyond a certain income threshold, suggesting a plateau effect in waste production among higher income brackets.

Table 1.21 *Tukey Post Hoc Test for Waste Generation*

Multiple Comparisons (Per Capita)						
Dependent Variable: kg/capita/day						
Tukey HSD						
(I) Income Group	(J) Income Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Low income	Middle income	-.159200*	.047811	.015	-.28675	-.03165
	High income	-.266200*	.047811	.000	-.39375	-.13865
Middle income	Low income	.159200*	.047811	.015	.03165	.28675
	High income	-.107000	.047811	.105	-.23455	.02055

High income	Low income	.266200*	.047811	.000	.13865	.39375
	Middle income	.107000	.047811	.105	-.02055	.23455
*. The mean difference is significant at the 0.05 level.						

5.6.2. Effects of Socioeconomic Status on MSW Composition

Considering income-related variations in waste composition and examining correlations with socioeconomic groups are important aspects of waste management research. As noted by Ogwueleka (2013), changes in income levels can lead to shifts in consumption patterns, which in turn influence the types and quantities of waste generated by households. Therefore, the researcher sought to investigate whether the descriptive variations observed in waste composition among the districts are statistically significant.

For each variable (see Table 5.4), the mean values, standard error, standard deviation, and 95% confidence interval for means at lower and higher bounds are shown. When comparing three or more independent groups on a continuous outcome with ANOVA, the assumption of homogeneity of variance is the second statistical assumption that needs to be tested. Homogeneity of variance ensures that the distributions of the outcomes in each independent group can be compared. Levene's test was used to test the Null hypothesis **H_0,** which states **that the variances are equal across income groups.** Where the output shows significance ($p < 0.05$), it is concluded that there is a difference in variance.

Table 1.22 *Homogeneity of Variance of Composition Data*

		Levene Statistic	**df1**	**df2**	**Sig.**
Paper	Based on Mean	45.939	2	117	.000
PET	Based on Mean	64.436	2	117	.000
Plastic Film	Based on Mean	9.788	2	117	.001
Metal	Based on Mean	35.882	2	117	.000
Glass	Based on Mean	24.225	2	117	.000
Food	Based on Mean	3.974	2	117	.021
Textile	Based on Mean	24.975	2	117	.000
Wood	Based on Mean	1.349	2	117	.264
Leather	Based on Mean	60.943	2	117	.000
Others/contaminated	Based on Mean	27.075	2	117	.000

The results in Table 5.8 demonstrate that the variances of most waste components across income groups are not equal, except for wood {$F(2,117) = 1.349$, $p = 0.264$}; this indicates that for most waste components, there are significant differences in the mean quantities generated by different income groups. Kim (2014) elaborates that larger F values in an ANOVA test suggest that the differences between group means are substantial compared to what would be expected by chance alone. In this study, PET ($F = 64.436$, $p < .000$) and leather ($F = 60.943$, $p < .000$) exhibited very high F values, indicating highly significant differences in waste quantities between income groups. These high F values imply that income levels strongly influence the generation of PET and leather waste. Conversely, the wood had a low F value ($F = 1.349$, $p = 0.264$), indicating no statistically significant difference in wood waste generation across income groups; this suggests that while income groups significantly differ in their generation of certain waste types, such as PET and leather, they do not differ much in their wood waste production, highlighting distinct trends in waste generation behaviour linked to income levels.

The One-Way ANOVA is generally considered robust to violations of the homogeneity assumption when sample sizes across groups are equal, as in this study ($n = 40$ in all groups). So even if Levene's test is significant, moderately different variances may not be a problem in balanced data sets (Pallant, 2016). However, Keppel (1992) suggests that a good rule of thumb is that if sample sizes are equal, robustness should hold until the largest variance is more than nine times the smallest variance. The descriptive statistics showed a large difference in variances among groups. For example, within the PET fraction, the standard deviation of the middle-income group (0.12246) is 12 times the standard deviation of the low-income group (0.01131). Given that the variance is the square of the standard deviation (SD^2), the middle-income group variance is 144 (12^2) times that of the low-income group. Hence, the general one-way ANOVA may not be reliable, which justifies using a Kruskal-Walis H test, a non-parametric alternative to the one-way ANOVA.

This statistical method was employed since the assumption of homogeneity was not met. The test does not assume normality in the data and is much less sensitive to outliers. For this study, the output compares the mean ranks and not the median since the waste components showed different distributions. For this test, the Null Hypothesis was H_0: some mean rank values of the waste fractions are the same across the three income groups if $p > 0.05$. Table 5.9 shows statistically significant outcomes ($p < .05$) for all waste fractions except wood {$H(2) = 2.017$, $p = .365$} with a mean rank score of 55.93, 66.63 and 58.95 for the low, middle and high-income groups, respectively.

Table 1.23 *Kruskal-Wallis Test for Effect of Socioeconomic Status on Composition*

Test Statistics[a,b]										
	Paper	PET	Plastic Film	Metal	Glass	Food	Textile	Wood	Leather	Others
Kruskal-Wallis H	45.650	55.298	21.337	42.231	55.449	14.354	49.008	2.017	72.245	27.170
df	2	2	2	2	2	2	2	2	2	2
Asymp. Sig.	.000	.000	.000	.000	.000	.001	.000	.365	.000	.000
a. Kruskal Wallis Test										
b. Grouping Variable: Income Level										

The interpretation of this analysis indicates that socioeconomic status significantly influences the composition of waste, with a strong effect observed across various waste fractions. The statistical evidence ($p < .05$) demonstrates a notable difference in the mean ranks of most waste categories, affirming that socioeconomic factors play a crucial role in determining the types of waste generated. Post hoc comparisons were conducted using Pairwise procedures to understand these differences further, allowing for detailed group comparisons. A Bonferroni adjustment was applied to mitigate the risk of Type 1 errors, which involve incorrectly rejecting the null hypothesis.

This adjustment involves dividing the original alpha level (0.05) by the number of comparisons (in this case, 3), resulting in a stricter significance threshold of 0.017. This method, recommended by Pallant (2016), ensures a more rigorous standard for establishing statistical significance, thereby providing more reliable results and reducing the likelihood of false positives in the analysis. The trend observed through this rigorous approach underscores the substantial impact of socioeconomic status on waste composition, revealing that higher or lower socioeconomic groups may produce distinctly different types of waste, which can inform targeted waste management strategies and policies. Key component outcomes of the post hoc tests are shown in Tables 5.10, 5.11 and 5.12 for interactions among groups for paper, food, and PET, respectively.

Table 1.24 *Pairwise Comparisons of Paper among Income Groups*

Pairwise Comparisons of Income Level (Paper)					
Sample 1-Sample 2	**Test Statistic**	**Std. Error**	**Std. Test Statistic**	**Sig.**	**Adj. Sig.[a]**
Low-income-High-Income	38.650	7.777	4.970	.000	.000
Low-income-Middle-income	50.150	7.777	6.449	.000	.000
High-Income-Middle-income	-11.500	7.777	-1.479	.139	.418
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050.					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 1.25 *Pairwise Comparisons of Food among Income Groups*

Pairwise Comparisons of Income Level (Food)					
Sample 1-Sample 2	**Test Statistic**	**Std. Error**	**Std. Test Statistic**	**Sig.**	**Adj. Sig.[a]**
Low-income-Middle-income	22.963	7.778	2.952	.003	.009
Low-income-High-Income	27.475	7.778	3.532	.000	.001
Middle-income-High-Income	4.512	7.778	.580	.562	1.000
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050.					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 1.26 *Pairwise Comparisons of PET among Income Groups*

Pairwise Comparisons of Income Level (PET)					
Sample 1-Sample 2	**Test Statistic**	**Std. Error**	**Std. Test Statistic**	**Sig.**	**Adj. Sig.[a]**
Low-income-High-Income	33.525	7.752	4.325	.000	.000
Low-income-Middle-income	57.375	7.752	7.401	.000	.000
High-Income-Middle-income	23.850	7.752	-3.077	.002	.006
Each row tests the null hypothesis that the Sample 1 and Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is .050.					
a. Significance values have been adjusted by the Bonferroni correction for multiple tests.					

Table 5.10 reveals a significant trend in waste composition between income groups, where the low-income group disposes of paper significantly differently than the middle and high-income groups ($p < .017$); yet, no significant difference exists between the middle and high-income groups ($p = 0.418$). This pattern is mirrored in Table 5.11 regarding food waste, with the low-income group again showing a significant difference in disposal patterns compared to the middle ($p = .009$) and high-income ($p = .001$) groups, while the middle and high-income groups exhibit no significant difference in their food waste disposal. Contrastingly, Table 5.12 presents a distinct trend for PET waste, where all interactions among low, middle, and high-income groups differ significantly ($p < .017$); this suggests that while paper and food waste disposal behaviours are more similar between middle and high-income groups, PET waste management practices vary significantly across all income levels.

5.7. Discussion of Study Findings

5.7.1. Current Trends in Waste Generation and Composition in Abuja

Solid waste composition and characterisation analysis are critical in resource recovery and the management of MSW. Based on explicit knowledge of waste generation rates and the percentage composition of MSW, a plan for strategies to prevent, reduce, separate, collect and recycle becomes more effective (Ugwu *et al*., 2020). Furthermore, it is crucial for decision-makers to have a thorough comprehension of waste streams in order to make informed choices regarding waste treatment and technology options (Khan *et al*., 2022). However, the lack of accurate and up-to-date waste generation and composition data in SSA countries, including Nigeria, poses a significant challenge to waste management planning and decision-making (Kadafa, 2017; Oteng-Ababio, 2014). Outdated data from the last census estimates in 2006 may not reflect the current waste generation rates and quantities, considering the substantial increase in population and high urbanisation rates over the years.

The three districts used for this study, Gudu, Gwarinpa and Maitama, are predominantly residential areas. The total amount of MSW generated during the sampling period from the combined districts was 498kg, involving 24 households and 153 residents. Gwarinpa district had the highest waste generation of 188.6kg and the largest household occupants, with 56 individuals. However, some researchers argue that household size is not always the determining factor for waste quantities. For example, while Trang *et al*. (2017) reported a positive correlation between household size and waste generation in their studies, a study on MSW composition in India by Ramachandra *et al*. (2018) found a negative relationship between waste generation and household size, but rather a correlation to income level. Trang *et al*. (2017) also pointed out that family structure is a key factor, and a household with mostly ageing occupants generates less waste than a household with younger occupants, regardless of the difference in household size. Generally, younger people consume more than older people (Chen, 2022); this can be attributed to various factors such as their inclination towards technological advancements, changing lifestyles, and higher disposable incomes. As a result, younger individuals often engage in frequent shopping activities, leading to increased household packaging waste (Chen, 2022).

Despite Gwarinpa generating the highest amount of waste during the study period, the per capita waste generation calculated for each of the sampled districts revealed that Maitama had the highest daily generation rate (0.78kg/capita/day) compared to Gudu (0.514kg/capita/day) and Gwarinpa (0.674kg/capita/day). Also, the findings show that waste generation increases towards the weekend, when residents spend more time at home, thereby increasing consumption rates and activities that result in waste generation. The observed pattern of increased waste generation on Fridays and Saturdays aligns with the typical behaviour of residents when they have more time to spend at home and engage in various activities.

A study by Dikole and Letshwenyo (2020) on waste composition in Botswana revealed a similar trend of waste increase during weekends. Likewise, the study also observed that this trend was only evident in middle and high-income areas. The explanation proposed by both studies suggests that individuals in low-income areas may be engaged in work activities during weekends, leading to less waste generation in their households, highlighting the influence of income and employment on waste generation patterns. Individuals in low-income areas may have different work schedules or be engaged in informal or labour-intensive occupations that limit their time at home during weekends. Consequently, the reduced presence at home may result in lower waste generation during weekends. This information is critical, particularly for the planning and designing waste collection strategies.

The average per capita waste generation from the three socioeconomic groups was 0.66kg/capita/day; this is consistent with previous studies conducted in the city and falls within the range reported by other researchers. For instance, Abur *et al*. (2014) reported a range of 0.59 kg/capita/day to 0.79 kg/capita/day for daily waste per capita generation in Abuja. Similarly, Kaza *et al*. (2018) estimated waste generation in middle-income economies, including Abuja, to be within the range of 0.5 kg/capita/day to 0.9 kg/capita/day. Using Equation 1 (see section 3.3.1.7.2), it was estimated that the daily waste generation in Abuja is 1,568 t/day; this indicates an increase in the daily amount of waste from findings by Abur *et al*. (2014) and the JICA (2018) studies which reported estimates of 828 – 1035 t/day, and 1,145 t/day respectively. However, the population difference in Abuja between the studies is a major factor.

Although the per capita waste generation seems to remain relatively stable, the findings in the composition study suggest that the overall daily waste generation in Abuja has increased over the years compared to the previous study by Ogwueleka (2012). The city‘s population has been rapidly growing, and as more people migrate to urban centres like Abuja in search of better economic opportunities, the waste generation rates also increase (Kadafa, 2017).

The waste composition analysis from the sampled districts, as summarized in Table 5.3, reveals that food (organic) waste is a significant component of the waste generated across the three districts. Additionally, waste categorized as "others" constitutes a substantial proportion of the waste in these districts. These findings align with the results reported by Abur *et al*. (2014) and JICA (2018), whose studies found that most of the MSW generated in Abuja comprises biodegradable matter that can be composted rather than disposed of. Another study conducted by Ebunilo & Sadjere (2017) in Sapele, Delta State, also reported similar findings, where the MSW generated by 100 households consisted mainly of organic or food waste, accounting for 75% of the waste composition. The high percentage of food waste in developing countries, as pointed out by Aderoju (2020), can be attributed to factors such as the consumption of unprocessed food.

In contrast, developed countries tend to consume more processed food. Unprocessed food generates more organic waste, including kitchen scraps, peels, and other biodegradable materials. This pattern of food consumption contributes to the larger proportion of organic waste in the waste stream of developing countries. The prevalence of food waste in the waste composition of the sampled districts in Abuja and other studies conducted in different regions of Nigeria indicates the significance of organic waste management in waste management planning.

A breakdown of the results showed that the Gwarinpa district generates a higher fraction of key components (paper 18.9%, PET 4.1%, leather/rubber 1.3%, and Plastic 13.1%) than the other districts. This may be related to the high rate of commercial activities and population density; this is similar to evidence from previous studies that indicate that organic waste represents the major component of MSW in developing urban cities in Nigeria (Lade *et al*., 2012; Babatunde *et al.,* 2013; Abur *et al.,* 2014; Afuno & Rabiu, 2017, Ezeudu, Ozoegwu & Madu, 2019; Ugwu et al., 2020).

The researchers Babatunde *et al*. (2013) looked at the composition of MSW in three local government areas (LGAs) in the state of Rivers and found that the majority of MSW was made up of organic waste, followed by paper and then nylon (plastic film). Similarly, a study conducted by Sadjere (2017) on the MSW produced by one hundred households in Sapele, Delta State, found that the MSW was composed of organic or food waste (75%), plastic and rubber waste (10%), paper waste (6%), glass waste (4%), metal waste (3%), and other waste (2%).

Afuno and Rabiu (2017) also reported that most cities and suburbs in Nigeria generally produce organic waste, and the volume of such waste increases exponentially during festive seasons and weekends. In another study by Ugwu *et al*. (2020), MSW in the Federal University Campus in Nsukka, Enugu State, composed primarily of organic materials (34%), plastic film (32%), paper (14%), plastic (9%), and others (11%). The evidence from these studies also revealed that MSW in Nigeria generally has a high organic content. Table 5.12 compares the waste composition data obtained in the current study with findings from two previous studies conducted in Abuja.

Table 1.27 *Means Comparison of Waste Composition Studies in Abuja*

Waste Fractions	**Composition % (Ogwueleka, 2013)**	**Composition % (JICA, 2018)**	**Composition % (Present Study 2021)**
Paper	9.7	8.23	12.93
PET	**	1.94	2.17
Plastic film	8.7	7.75	10.53

Metal	3.2	2.48	1.50
Glass	2.6	1.03	1.23
Food	63.6	52.75	45.87
Textiles	1.6	0.48	1.20
Wood	-	1.63	2.33
Leather/Rubber	-	0.12	0.67
Others	10.6	24.59	22.57

(Note: **combined with plastic film as a single component)

The table shows food as the predominant waste component in the three studies. However, the proportion of food waste tends to decrease between 2012 and 2021, from 63.6% to less than half of the overall sample (45.87%). This reduction could be attributed to various factors, such as improved waste management practices, increased awareness of food waste reduction, or changes in dietary habits due to urbanisation and economic development. A similar pattern is also observed for metal, which decreases from 3.2% to 2.48% and 1.50% for 2012, 2018 and this study, respectively; this may indicate the high demand for scrap metal through the activities of waste pickers.

In contrast, the combined plastic waste components (PET & Plastic film) increased from 8.7% in 2012 to 9.69% in 2018 and 12.70 in this study. The production and consumption of plastics have increased significantly over the past few decades, leading to an alarming rise in plastic waste generation. One of the primary reasons for the global nature of the plastic waste issue is the widespread use of single-use plastics in various industries, such as food and beverage, packaging, and consumer goods. In the context of Abuja, single-use plastics, such as plastic bags, bottles and water sachets, are often discarded indiscriminately, contributing to waste management issues in the city.

However, the differences in proportions of waste components between the studies compared may be influenced by methodological differences, sample size differences or seasonal variations during the sampling periods for the different studies. Nonetheless, the consistent trend of a potential decrease in the organic fraction of MSW in Abuja is worth noting. The insights provided by Kaza *et al*. (2018) on the relationship between development and organic waste reduction align with the context of Abuja's rapid development and urban renewal, as reported by Abubakar (2014) and

Unah (2021). According to Hoornweg and Bhada-Tata, as a city experiences urbanisation and economic growth, specific patterns tend to emerge in waste generation and composition, including a potential decrease in the organic waste fraction.

The results of the composition in this study are substantiated by the survey findings on waste composition, detailed in Chapter Four (see Table 4.3). A mean descriptive analysis of the questionnaire survey reveals that participants predominantly identified food waste as the primary component of municipal solid waste (MSW) generated, with a mean score (M) of 2.64 and a standard deviation (SD) of 0.051; this is followed by paper waste, which had a mean score of 2.23 and a notably higher standard deviation of 0.53, indicating greater variability in the responses. Plastics were ranked third, with a mean score of 1.99 and a standard deviation of 0.013, suggesting consistent agreement among participants regarding their composition. The trend highlighted by this analysis indicates a clear hierarchy in the types of waste generated, with food waste being the most prevalent, followed by paper and then plastics. This trend underscores the importance of focusing waste management strategies on reducing food waste and improving recycling efforts for paper and plastics to effectively address the predominant components of MSW.

5.7.2. The Effects of Socioeconomic Status on Waste Generation and Composition

A one-way ANOVA also showed strong evidence of a significant difference in waste generation per capita among the income groups {$F(2,12) = 15.699$, $p < .05$}; this supports the findings of Ramachandra *et al*. (2018) and Kala & Bolia (2020), that income influences waste generation. However, a Tukey post hoc analysis showed that while per capita waste generation in the low-income group differed significantly from the other two categories, no significant difference was established between the middle and high-income groups; this may suggest an improved lifestyle and increased consumption in the middle-income district, or it is possible that the number of occupants in some households in this was underreported.

The high-income group had the highest proportion of food waste (52.2%), followed by the middle-income (45.1%) and the low-income group with 37.3%; this is contrary to findings in the literature, which showed the highest organic fraction among low-income groups. For example, Dikole and Letshwenyo (2020) studied household waste composition in Botswana. They found that while low-income households generated about 80.78% of organic waste, middle and high-income households generated an average of 70% and 77%, respectively. Similarly, Ogwueleka (2013) reported 66.1%, 63.9% and 58.7% for low, middle and high-income groups respectively. However, the JICA (2018) report showed similar findings to this study, with the low-income group having the lowest organic fraction (46.74%) compared to the middle-income (57.63%) and the high-income (53.89%).

A probable explanation for this could be a change in consumption patterns in low-income households resulting from economic hardship, especially during this study, conducted immediately after the pandemic eased. Another possible reason could be using food waste to compost among low-income households; this cannot be ruled out, as many low-income earners in Abuja have resolved to do yard farming to provide food for their families. While these findings highlight the potential for resource recovery and sustainable waste management practices among low-income communities, forecasting possible changes in waste composition is crucial to WtE technology selection (Khan *et al*., 2022).

Another significant finding is the high proportion of the component 'others', mainly ash and other contaminated waste, among low-income households. This observation may be explained by the involvement of waste-picking activities and waste burning within these households. In low-income areas, waste-picking activities are prevalent as a means of livelihood for vulnerable individuals seeking to collect recyclable materials from waste bins and dumps to sell for income (Ogwueleka & Naveen, 2021). These waste pickers often sort through mixed waste to extract recyclable items like plastics, glass, and metals.

A Kruskal-Wallis analysis was conducted to compare the mean ranks of various waste components among three socioeconomic groups, revealing a significant difference ($p < .05$) for all components except wood, indicating notable variations in waste composition across these groups. A Pairwise comparison test with a Bonferroni-adjusted alpha level ($p = .017$) was performed to identify specific differences. The post hoc test summary showed that for paper and food waste components, the low-income group differed significantly from both the middle- and high-income groups, while no significant differences were observed between the middle- and high-income groups for these components. However, the plastic components presented contrasting trends: PET waste showed significant differences across all three income groups, whereas plastic film only showed significant differences between the low-income and middle-income groups. These findings suggest that socioeconomic status influences waste composition, with lower-income groups differing more markedly from higher-income groups in their paper, food, and specific plastic waste outputs.

5.8. Chapter Summary

This chapter has presented an in-depth analysis of the waste composition study recently conducted in Abuja, aiming to assess current trends in waste quantities and composition across different socioeconomic areas. The study offers valuable insights for policymakers and stakeholders to make informed decisions about waste management and environmental sustainability. Three districts were selected for the study: Gudu (low-income), Gwarinpa (middle-income), and Maitama (high-income). One hundred twenty waste samples were collected from 24 households over five days, resulting in 498 kg of municipal solid waste (MSW). The per capita waste generation was 0.66 kg/capita/day, with an estimated daily waste generation of 1,568 tons for the entire city.

The findings indicated a rapid increase in waste generation in Abuja, with organic waste remaining the predominant component. However, there was also an increase in recyclable components like paper and plastics. The study revealed that socioeconomic status significantly influences waste generation and composition. Notably, the low-income district exhibited distinct differences in waste generation compared to the middle- and high-income districts. Additionally, socioeconomic status impacted the waste composition, with significant differences observed for all waste fractions except wood.

These results underscore the need for targeted waste management strategies tailored to each district's specific characteristics; this approach can enhance waste reduction, recycling, and resource recovery efforts. The findings suggest that Abuja has significant potential for Waste-to-Energy (WtE) projects, which could address the increasing waste generation and contribute to sustainable development, resource recovery, and clean energy production. As discussed in Chapter Seven, the composition study‘s findings are crucial for adopting WtE technology in Abuja.

The next chapter (Chapter Six) introduces the second phase of the explanatory sequential design, presenting qualitative research findings. This phase will comprehensively understand waste management challenges and barriers in Abuja, combining quantitative and qualitative approaches to support evidence-based decision-making in waste management practices.

Chapter 6: A Qualitative Perspective of Waste Management in Abuja: The Barriers

6.1. Introduction

Developing countries face a critical challenge in managing waste sustainably, with various barriers impeding effective waste management practices (Cobo *et al.,* 2018). These obstacles significantly affect the environment, public health, and socioeconomic development. Effective waste management is a major concern in Abuja, and it is essential to identify the obstacles hindering its success in developing sustainable solutions. Chapters Four and Five concluded the first phase of this study by exploring the current state of waste management in Abuja, highlighting the challenges and trends in generation and composition. An analysis of the survey responses revealed low collection rates, unwillingness to pay waste fees, low public participation, open dumping, lack of information and communication, and poor segregation and recycling practices as part of the prevalent challenges in the city. Furthermore, key findings from fieldwork carried out by the researcher revealed an estimate of per capita waste generation at 0.66kg, amounting to 1,568 tonnes of MSW generated daily.

This chapter introduces **Phase 2** of the study design and highlights the FGDs' findings with waste sector experts on the barriers to sustainable waste management in Abuja. As previously mentioned in the study introduction, in the context of this research, "barriers" refer to the confounding obstacles to mitigating the challenges investigated in the quantitative study. Therefore, this chapter explains why the challenges are prevalent in Abuja. Given the explanatory sequential design of this study, the FGDs on barriers to waste management explain and give further insight into the waste management challenges. A detailed discussion and justification of the sequential approach to the qualitative study are presented in Chapter Three.

The FGDs were guided by the questionnaire survey results, which address **RQ1.** Inferences were also made during the discussions with the waste composition study results, which address **RQ3** and **RQ4**. Hence, the research question guiding this study is **RQ5:** What are the barriers to sustainable waste management in Abuja? As a result, the qualitative instrument (Focus Group Agenda) was designed to elaborate (Schooneboom & Johnson, 2017) on the findings of the quantitative study, thus linking both phases and allowing for further insights from the experts.

6.2. Focus Group Analysis and Results

For this study, two virtual sessions were held on Zoom guided by the same agenda, and the discussions were merged for analysis. As discussed in Chapter Three, the participants were public and private sector workers of experienced operational staff from AEPB, private contractors working with the government agency, and representatives from the local council (AMAC) and the Federal Ministry of Environment. For each session, which lasted approximately 60 minutes, the researcher served as the moderator and was responsible for managing the proceedings. Discussions on waste management issues began after the introductions and the ice-breaking session with participants. The objective was to explore waste management further and to understand the challenges highlighted in the quantitative analysis. As the discussion delved deeper into the issues, the conversation naturally shifted towards the expert‘s opinions on the underlying reasons for the challenges.

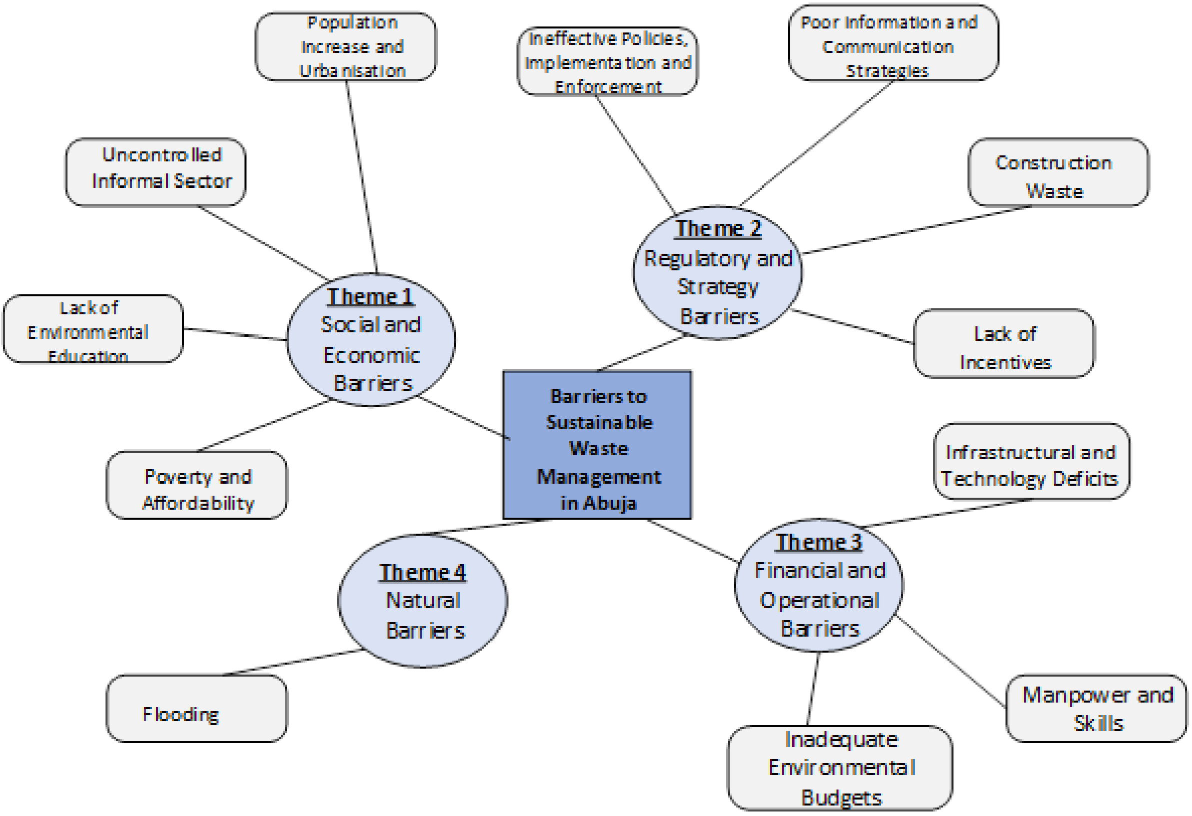
The expert perspective and insights on the "why" behind these challenges provided valuable context for the barriers to sustainable waste management in Abuja and potential solutions. Table 6.1 summarises the codes assigned to the 11 participants to allow for anonymity. As a reference point for the researcher, participants in the first FGD were assigned codes with “**A**”, while those in the second meeting were coded with “**B**”.

Table 1.28 *Participant Codes*

FGD 1 & 2			
Code	**Organisation**	**Position**	**Years of Experience**
A1	AEPB	Land Resource Officer	9
A2	AEPB	Supervisor	7
A3	AEPB	Supervisor	7
A4	AMAC	SCI Officer II	5
A5	Contractor	Head Operations	8
A6	Contractor	Supervisor II	5
B1	AEPB	Supervisor	7
B2	Federal Ministry of Environment	Supervisor	8
B3	Contractor	Team Leader	7
B4	Contractor	Supervisor I	6
B5	Contractor	Operations/Driver	7

The FGD transcript was subjected to deductive and inductive coding and analysed using thematic analysis. Plano Clark and Creswell (2018) posited that the best approach in an explanatory sequential design is to determine how the qualitative themes and codes provide additional insight into and nuances of the quantitative data. Therefore, the analytical framework for the study was informed by barriers reported in the SWM literature and applied by Guerrero *et al*. (2013), Yukalang *et al*. (2017), and Ezeah and Roberts (2012). In order to categorise and organise the qualitative data gathered, the NVivo (2022) software tool was employed. By utilising this software, the researcher managed the qualitative data collected efficiently. As a result, several themes emerged from this process. Figure 6.1 shows a thematic network analysis of the emergent themes.

Figure 1.32 *Thematic Network Analysis of Emergent Themes*



A weaving technique was used to integrate the qualitative findings with the quantitative findings of the FGDs in the discussion; this gave a holistic picture of the current waste management situation in Abuja. Fetters *et al*. (2013) acknowledge that this integration method works well for explanatory designs where the researcher initially presents the quantitative results separately within the report. The following sections explore the themes more deeply by incorporating insights from experts shared during the discussions.

6.3. Barriers to Sustainable Waste Management in Abuja

6.3.1. Social and Economic Barriers

In the broad context of the discussion on waste management challenges in Abuja, the experts highlight the impact of societal and economic constraints under four sub-themes. These subthemes are discussed in the following subsections.

6.3.1.1. Population Increase and Urbanisation

The population explosion in Abuja poses significant challenges to the city's development and sustainability. As discussed in Chapter Two of this study, a significant cause is rapid urbanisation, and a relative consequence is increased waste generation. The participants gave insights into the increasing population as a significant limitation for sustainable waste management in Abuja. Empirical evidence shows that the population of Abuja increased from 1,406,239 to 3,564,126 between 2006 and 2016 (NBS, 2016) and based on the findings in the composition analysis in this study (see section 5.4.1), an estimated 1,568 tonnes of waste is generated daily in Abuja. Furthermore, evidence from the QUAN results showed a positive relationship between waste collection frequency and waste generation, r (343) = .107, p = .029. Participant B1 gave his opinion on how increased population affects urbanisation and waste management.

> *"The demand for collection is sometimes beyond our capacity, especially in those districts like Gudu and Gwanrinpa that are highly populated and have a lot of commercial activities. We disrupt our schedule sometimes because bins get filled up quickly, causing some areas to look dirty. So, we get frequent calls in those areas to come and evacuate waste. It never used to be like that when I started working here".*

This statement by Participant B1 above reveals the mounting challenges waste management authorities face with a sense of concern from the participant's tone. It highlights a significant surge in demand for waste collection services, outpacing the authorities' capacity to maintain regular schedules. Rapidly filling bins disrupt collection routines, leading to delays and untidy surroundings, prompting increased service requests from residents. From the participants' narration, this situation contrasts with the past, indicating a notable escalation in waste generation and service demands over time. Participant A3 showed how increasing commercial activity further contributes to indiscriminate dumping in this area.

> *"I think many unapproved mini-markets are springing up in some of these highly populated areas to meet the demands of the population. This really affects our planning and results to waste being dumped indiscriminately. Roadside sellers are even more common at night, and this makes enforcement more challenging. In my area, after the market is shut for the day, many sellers move their stalls to outside the market premises and on the roads to continue their business, and they don't clean the areas after they finish selling".*

One of the contractors (A6) agreed to this issue of waste generation through increasing population by adding that:

> *"The gutters in Gwarinpa get blocked frequently, and I think it is because there are too many roadside sellers".*

'Gutters', as Participant A6 above employs, is a colloquial term for drainage in Nigeria. As Participant A6 mentions, the blockage of these drainage systems is due to the increased number of roadside sellers; this infers that the roadside sellers appear to dump the waste materials from their commercial engagements into the drainage systems. Furthermore, B5 exposed that the increase in population has led to traffic affecting waste collection and disposal.

> *"We are facing the issue of traffic due to population increase, which never used to be in Abuja. The number of cars in the city has increased and even the ring roads are affected. Sometimes we are forced to abandon collection or wait till after closing time at night because of traffic, so we can access the Gosa dumpsite".*

This opinion of B5 explained the findings in the quantitative study that showed that 31.6% of waste collection is carried out at night. The discussion, therefore, highlighted the impact of the population increase in Abuja on waste collection, indiscriminate dumping and waste generation.

6.3.1.2. Uncontrolled Informal Sector

Informal waste pickers play a critical role in waste management in developing countries. While acknowledging the contributions of the informal sector, the experts also explained some challenges in relation to their activities. It was revealed in the quantitative study that approximately 40% of waste collection is carried out by waste pickers, and their activities are not restricted to any of the sampled districts. Building on this, A3 explained why there is increasing informal sector activity in the collection of waste by stating:

> *"I'll say a major contributing factor is the number of people flocking into Abuja in search of work. Many waste pickers are young men from neighbouring states searching for means to earn a living. Their numbers have increased greatly over the years, and they have their own networks, mostly controlled in the form of a family business although many of the young men also work individually. It is difficult for the board to control their activities. They are even frequent visitors to the estate I live in".*

Participant A3 above appears to present insight based on the personal and lived experiences of young men who have emigrated from neighbouring states. The use of familial networks by young men presents a challenge for the authority in controlling their activities, hence presenting a barrier to effective waste management approaches. In agreement with A3, participant A2 related the issue of open dumping to the activities of waste pickers by pointing out that:

> *"Their activities are illegal and sometimes contribute to problems. We have tried to restrict them to the peripheral parts of town but because they are in search of valuables and recyclables like plastic bottles, they find a way to get back into the city and end up contributing to littering waste by scattering unwanted items from bins. Personally, I recognise the fact that they assist in waste evacuation and recycling but there is a need for some form of collaboration so they can be properly trained, monitored and regulated".*

The statement above by A2 highlights the dual nature of waste pickers' activities: while they aid in waste removal and recycling, their illegal presence often worsens littering issues by scattering refuse. A2 proposes collaboration with waste pickers to formalize their role and enable training, monitoring, and regulation to mitigate adverse impacts while harnessing their contributions to waste management. Building on this information, A3 added on how gutters and streets are polluted by improper dumping:

> *"Some of the littering you see, especially within the highbrow neighbourhoods like Maitama, is artificially caused by waste pickers who sort their waste within*

these areas to reduce their load. When they evacuate waste from households, you'll expect them to take it to the central collection point, but they rather carelessly throw the nonrecyclables into gutters or litter the streets after getting what they want".

In addition, he explained that:

"…. *not all of them operate with pushcarts so they use carrier bags and tend to scavenge around the bins at households using crude methods. Some focus solely on single streams of recyclables like metals which results in them overturning the bins to search."*

The quantitative results showed that of the 343 participants, only about 24% were either always or often willing to pay for waste services, while the majority (43.1%) were either rarely or never willing. Participant B4's opinion linked informal waste pickers' activities to people's unwillingness to pay for waste services. B4 explained the unwillingness of people to pay for waste services:

"I think people look for the cheapest way to dispose of waste regardless of the risk. Furthermore, informal waste collectors sometimes even pay to get recyclables from people or operate a trade-by-barter system where they dispose of your waste in exchange for recyclables. These arrangements make people unwilling to pay for our services when rendered by us and you can't blame them in this case because our charges can't match theirs. Because of this, a lot of people patronise them.

The participants' views on informal waste pickers were similar and in agreement. While it was acknowledged that waste pickers play an important role in waste collection and recycling, they also pointed out that their activities may cause littering and unwillingness to pay for waste collection.

6.3.1.3. Lack of Environmental Education

Environmental education is crucial in increasing awareness and understanding of various issues, including waste management (Debrah *et al*., 2022). The participants constructively raised the issue of the lack of environmental education programmes as a cause of some of the waste management challenges in Abuja, particularly poor segregation and recycling practices. Evidence from the quantitative results showed that while the participants reported average awareness of recycling and reuse, there was low knowledge of segregation, waste reduction and WtE. Furthermore, it was revealed that approximately 68% of the respondents rarely or never segregate their waste, while over half (51%) of the respondents do not practice recycling. Building on the information, A5 explained the lack of awareness among the individuals on the environmental concern of waste:

> *"I feel many individuals are not aware of the importance of recycling and waste segregation, which is a missed opportunity to treat waste as a resource and contribute to energy recovery. The lack of education programmes is leading to more waste being improperly disposed of, which is harming the environment and creating health hazards. It's important for individuals to educate themselves and take responsibility for their waste to ensure a cleaner and safer environment for everyone".*

A5 argues for increased public awareness and education on recycling and segregation to transform waste into a valuable resource and facilitate energy recovery. From A5's narrative, without effective educational initiatives, improper waste disposal persists, posing environmental risks and health hazards, emphasising the importance of individual accountability for waste management and environmental sustainability. B2 explained how several individuals separate only the waste which can be sold to earn money while disposing of the rest in the open. The quote from B2 below highlights the selective approach to waste segregation driven by financial incentives, mentioning the necessity for broader awareness campaigns to promote the segregation of all waste types, including organic waste:

> *"Awareness is a problem because some people now know that they can sell plastic bottles to some waste pickers, so they reserve them after use to earn some cash. It means they only segregate what they believe is beneficial to them. This shows the need to be made aware of the potential of segregating even organic waste. I think there's a need for educative campaigns to drive awareness of the potential of energy recovery from waste, especially with regard to electricity generation.*

On the other hand, B1 argued that even selling the bottles is not a solution to the problem:

> *"But after selling the bottles, the same people throw the remaining waste in the gutter". Do we need to educate them on the diseases resulting from dirty environments?"*

Responding to this, B2 further explained that the uncontrolled disposal of municipal waste by dumping it and leaving the responsibility to the government further aggravates the problem. The participant appears to express disappointment about the prevalent misconception among residents that waste management is solely the government‘s responsibility, leading to widespread illegal dumping. Again, like other participants above, B2 advocates for an increase in educational programs.

> *“I think it‘s unfortunate that most of the municipal solid waste in Abuja is being dumped on land in an uncontrolled manner. This is primarily due to the convenience factor, as people believe that waste management is solely the responsibility of the government and that the government will eventually come and clean up the mess. As a result, people continue to dump their solid waste anywhere they can find space, including in gutters and on open land along the road. Educative environmental programmes would make people aware that waste management is everybody’s responsibility and that there are benefits to recycling and segregating waste.”*

Furthering the discussion, A5 note how convincing individuals of waste segregation requires the adoption of appropriate technologies :

> *“It is difficult to convince people to segregate their waste because they don’t see the need. People think it is a waste of time. With the plans to adopt technologies I feel advocacy for segregation should be a primary focus.”*

6.3.1.4. Poverty and Affordability

Waste management services are an essential utility that incurs costs. These costs relate to waste collection, transportation, recycling, treatment, and disposal. To have an effective waste management system, these costs are covered by public funding, service fees, or a combination of these. Unfortunately, many households may struggle to afford these fees in impoverished areas. In the survey, the experts highlighted the issue of poverty and affordability by expanding on the willingness to pay for waste services. Participant A5 explained how the economic situation is impacting the willingness to pay for waste collection:

> “*The economic situation in the country has generally not been easy, especially since the pandemic, and this has contributed to negative practices and the reluctance to pay for collection. It is mainly those that can afford it that comply”.*

In response, A1 partly argues that there has been a historical issue with getting payments for waste collection. Participant A1 appears to suggest that while the economic situation is a factor, waste collection payments have always been poor:

> *"I think despite the economic hardship, people do not feel it's necessary to pay for waste because getting payments has always been a problem. I think it may be related to the fact that there are other alternatives, like dumping, burning, and more affordable waste pickers. I'll rather say it depends on your socioeconomic class because those who live in affluent areas don't complain about paying for waste collection."*

A2 developed on the argument and explained that lack of money is resulting in searching for cheaper alternatives to payment for waste collection:

> *"I believe the level of poverty has worsened the situation because people in the areas we cover are more frequently complaining of a lack of money. It is the economic situation that drives them to patronise the waste pickers who offer cheaper alternatives. We even encounter some cases of those that are living in high-brow areas that are not willing to pay for waste collection because they may feel it is no longer one of their priorities."*

The opinions of the participants on higher-income earners being more willing to pay relatively explain the Kruskal-Wallis tests showed a statistically significant difference in willingness to pay among districts, $H (4, n = 343) = 21.25, p < .001$, and subsequent post hoc analysis revealed a statistically significant difference between the low-middle income district, Durunmi (135.52) and the middle-income Gwarinpa (194.66), ($p<.001$). However, there also seemed to be some discordance as no statistical significance was found between the low-income district (Gudu) and the high-income district (Maitama); this may support the argument of Participant A2 that there may be high-income earners who are not willing to pay.

6.3.2. Regulatory and Strategy Barriers

Regulatory and strategy deficits in waste management have become a significant concern recently. The lack of adequate regulations and strategic planning has resulted in various challenges and negative environmental and public health impacts.

6.3.2.1. Ineffective Policies, Implementation and Enforcement

In line with achieving the SDGs, the National Policy on SWM in Nigeria (2017) consists of a declaration of purpose and is carried out as a procedure or protocol; this gives the federal and municipal authorities a clear focus on addressing MSW issues in Abuja through its institutional functions and policy guidelines. The FGD participants echoed this and the role of policy and strategy context in MSWM in Abuja. Empirical evidence from Phase 1 showed that approximately 68% of the respondents disagreed or strongly disagreed that the environmental sanitation policy is effective. Furthermore, over half of the respondents (52%) indicated that they rarely or never participated in the sanitation exercise. The participants then shared different views.

Views from Participant B2 below canvasses for cohesive waste management policies aligned with SDGs, stressing streamlined approaches and private-sector involvement. At the same time, the second insight underscores the gap between policy intentions and outcomes, urging prioritised enforcement and implementation for tangible improvements in waste management practices:

> *"I believe it's important to have a cohesive policy and strategy context when it comes to waste management and achieving the SDGs. Our policies and regulation are fragmented and difficult to implement effectively allowing for wasted time and resources, as well as corruption. Government is making efforts but we need to work towards more streamlined approaches that encourage private-sector investment and promote sustainability. By doing so, we can create a cleaner and healthier environment for everyone."*

> …… *the environmental sanitation policy, in my opinion it hardly achieves its aim because we are still experiencing some environmental issues resulting from poor waste management practices. Attitudes towards sanitation exercises are declining. People are not willing to participate. We need to prioritise enforcement and implementation to see better results.*

Views from B1 described the situation in Nigeria, observing that sold waste collection relies to an increasing extent on the informal economy. Reflecting the views of other participants, he expressed the opinion that regulations are needed in order to ensure customers receive a reliable service:

> *"The mobile courts aided enforcement and had an effect initially but after a while people went back to the old ways because the courts lacked independence. It became a man-know-man thing."*

The quote above from B1 highlights how corruption and nepotism have impacted mobile courts' enforcement activities; this is reflected in the phrase ‘man-know-man’ employed by B1. This phrase is a colloquial expression of nepotism, as it is frequently employed in Nigerian local pidgin English. Continuing the discussion, views from A6 underscored the need for continuous monitoring and evaluation in contrast to dedicating only a day in a month to promote waste management practices. Additionally, like other participants in the current study, A6 also mentions the importance of increased public education:

> *“I don’t think setting aside one day in the month is an effective way of promoting proper waste management practices.” Rather than just enforcement, there is a need for monitoring and evaluation to assess the effectiveness of the policy. The reason why people even come out to participate on sanitation days is just to comply and not because of their desire to maintain the environment. It is more of a ritualistic exercise and may not be an adequate independent long-term strategy. If we must adopt new technologies, then I think there should be a shift in the policy.”*

> “…. *the procedures set out for the implementation of this policy is to drive public education and awareness and I think Government has not done enough on this.”*

Views from A2 focussed on how the knowledge of the dissemination of information on cleanliness and sanitation is essential not only for the maintenance of the ecosystem and environmental balance but also for improving the economy:

> *“I think the general view is that the sanitation policy focuses simply on a few actions necessary to maintain the cleanliness of the environment with an aim to curtail disease spread. But in the real sense, the policy has wider objectives, like promoting waste management practices that are not just beneficial to the environment but also to the economy. Implementing the other areas of focus has not been possible because enforcement merely drives cleanliness without putting forward segregation or recycling as objectives. I think Government needs to establish indicators and evaluate sanitation-related performance and service standards. Policies need to be informed by comprehensive data and research.”*

The discussion shows that the experts believe that ineffective policies, poor implementation, and enforcement strategies are contributing to the current state of waste management in Abuja, and they questioned the strategies driving the environmental sanitation policy.

6.3.2.2. Poor Information and Communication Strategies

Information and communication are critical to improving knowledge and awareness and driving public participation in waste management (World Bank, 2021). The quantitative results showed a paucity of information on waste management, as approximately 64% of the respondents reported rarely or never receiving information. To explain this issue, B1 furthered that there is a serious paucity in the availability of information regarding the significance of waste management in Nigeria:

> *"There used to be some radio programmes concentrating on waste management sponsored by the ministry but, most have stopped now. Some of the radio programs that were sponsored by the Ministry were very popular and had a large following. They were an important source of information for people who did not have access to other forms of media, such as television or the Internet, so I'm not surprised that people rarely receive information."*

The argument from B1, as quoted above, complements previous points by participants who advocated for increased awareness about waste management. B1's statement above suggests that the employment of mass media in communicating waste management was proving effective, as B1 mentions that, for example, the radio programs were 'very popular and had large following'. B2 argued that modern technological advancements and the school curriculum should be used to transmit the message of waste management to the younger population. This emphasis appears to highlight the importance of ensuring the younger population understands the importance:

> *"There are still some radio programmes the ministry co-sponsors with assistance from some NGOs which are run in pidgin English and local dialects. Some NGOs introduced the idea to promote information due to low public attendance in their community-based campaigns. I think the real issue is that there is a need for a more holistic approach because many people hardly listen to the radio these days. I am aware of the programmes, but I've never had the time or opportunity to listen in.*

B2 further noted that using the internet along with school education can be a solution to solve this growing concern of waste management:

“In reaching out to the younger generation, I think utilising the internet would be a good communication strategy.” More so, there are hardly any government-driven school education programmes and not enough aspects of waste education activities are part of school curriculums. I believe revamping our market campaigns can help at the community level.

The opinion of A2 was that the use of signs or billboards to remind people can be an easy and better alternative:

“I think there is a need to invest in more signage and billboards in strategic locations to serve as constant reminders and communicate the message, while people carry out their daily activities.”

From the discussion, the experts explained that the lack of information on waste issues stems from poor strategies and limited reach due to the communication mediums and highlighted the need for inculcating the youths through education.

6.3.2.3. Construction Waste

Like in most developing economies, there is a lot of construction activity within the Abuja municipality. The experts shared their views on how the influence of construction activity exacerbates open dumping in Abuja. On the influence of poor construction waste management, B1 explained that it is one of the sectors where the concept of waste management is taken least care of and highlights the role of construction activities in contributing to waste accumulation, urging for comprehensive waste management strategies that address the disposal practices of various sectors beyond traditional household waste:

“I think construction activities are also part of the problem. Some of the waste dumps within the districts originated from construction materials. Unused or demolished blocks and other waste materials are usually dumped carelessly by construction workers when projects are abandoned or completed, encouraging the public to convert these dumps over time to permanent dumpsites. I think our strategies need to cover other sectors to avoid such influences on public behaviour.”

B1 further noted that temporary settlements for the construction workers and their families end up displaying poor waste management:

"…..many construction sites do not make adequate arrangements for accommodating workers on site permanently during projects. Some workers even move their families to the site introducing temporary settlements and end up displaying poor waste management practices around the vicinities. Such arrangements are not captured in collection planning so it ends up becoming an issue for waste collection and payments."

6.3.2.4. Lack of Incentives

In developed countries, incentives have inspired citizens to recycle their waste materials. The participants proposed that the poor segregation and recycling practices revealed by the quantitative study are due to the lack of incentives to increase such practices. Some views are highlighted below. Views from B2 argue for more financial rewards and incentivisation to encourage individuals to use positive waste disposal practices. B2 appears to suggest that this approach will complement the existing recognition of the value of waste management since individuals already reserve wastes to sell to informal waste pickers:

"The fact that some people reserve and sell their plastic bottles to informal waste pickers shows that there is a bit of recognition of the value of waste. I believe government can entice people to recycle on a general scale using incentives."

Along the same lines as the requirement for incentives and the need for social upliftment programmes, B4 provided insight into how organisations are employing incentivisation to encourage positive waste management practices from the population:

"*Some private organisations have started such programs but it is appealing to only few people, mostly those in the low-income areas because the incentives may not really be worth the time of others."*

"…..Lagos has more of such initiatives possibly because they generate a lot more waste due to population, but I think a general policy for incentives would create more awareness and bring change nationally."

6.3.3. Financial and Operational Barriers

Funding is crucial in waste management in developing countries (Ganda, 2020; Hoinaru *et al.,* 2020). It is an overarching barrier that hinders the effective implementation of waste management initiatives. Responsible agencies and organisations struggle to fulfil their duties and responsibilities without sufficient financial resources. Waste management encompasses a range of activities, including waste collection, transportation, treatment, and disposal. Each step requires adequate funding to ensure smooth operations and implement the necessary infrastructure. However, due to limited financial resources, many developing countries face significant challenges in maintaining an efficient waste management system (Zhang *et al*., 2019). The experts highlighted how financial and operational constraints limit effective waste management in Abuja.

6.3.3.1. Infrastructural and Technical Deficits

Without the necessary infrastructure and technology, waste management becomes inefficient, leading to waste accumulation, pollution, and health risks. The quantitative results showed a negative correlation between waste collection frequency and open dumping, $r(343) = -.113$, $p = .017$, suggesting that open dumping likely increases due to delayed waste collection. The experts highlighted critical shortfalls that cause waste collection delays and do not foster recycling and segregation behaviours.

In the quote below, Participant B3 presents the operational challenges faced by waste management agencies, particularly regarding vehicle availability and breakdowns, which impact service delivery. While acknowledging the need for improved infrastructure, B3 emphasises the importance of addressing such logistical issues to enhance efficiency and mitigate negative perceptions of service quality:

> "*Sometimes the delays are due to the non-availability of compactor vehicles due to frequent breakdowns. Even though I don't agree that delays are a good excuse to portray such negative attitudes, we need to procure more vehicles to be able to effectively service our coverage area."*

B5 also had the same opinion and added that the compactors could be the solution as the movement of open trucks bearing wastes makes the locality unhygienic due to constant foul smell:

> *"In my opinion, we need compactors because open trucks do not always serve the purpose. We are unable to navigate through some parts of the central city areas with open trucks during the day because of the smell, prompting us to work at night."*

The quote from B5 above highlights the practical necessity of compactors over open trucks for waste collection in urban areas, especially in central city locations. The quote mentions odour issues, reflecting that waste management professionals are concerned about the impact of waste management operations on the environment and public health. Furthermore, B5 emphasised the need for other infrastructure, particularly for recycling:

> *"…Government needs to provide more transfer stations and recycling facilities within the city."*

Concerning segregation and recycling behaviour, A2 noted that colour-coded bins should be set up on an immediate basis:

> *"I think the lack of colour-coded bins around the city does not help in encouraging segregation and recycling."*

Furthermore, A2 advocates for the employment of modern technologies in waste management procedures while canvassing for more government investments in this area:

> *"….there is hardly any technological input in our waste management processes. I think the government needs to speed up investments in updated and efficient technologies that can enhance significantly waste treatment and disposal."*

6.3.3.2. Manpower & Skills

Any waste management system relies on human resources and skills. Waste workers require training to function effectively and ensure the efficient collection, sorting, recycling, transportation, and disposal of waste. They also participate in enforcement. On the issue of manpower, A3 noted that the lack of staff to drive enforcement of waste management regulations is aggravating the problem:

"I think people get away with indiscriminate dumping because we rarely have enough staff to drive enforcement. The growth in population is confounding the issue. We need more staff to be able to enforce waste management laws."

A6 stated that the lack of necessary skills, along with the lack of hands, is hindering the workflow:

"We struggle with coordination most times because of lack of hands. Even when we use ad-hoc staff, work doesn't flow smoothly because most of them lack the necessary skills."

A6 above highlights the importance of having a skilled and adequately staffed workforce for efficient waste management operations. The mention of coordination challenges highlights the need for effective management and organisation within the workforce. Additionally, the reliance on ad-hoc staff suggests a potential need for more permanent, trained personnel to ensure consistency and proficiency in executing tasks. Addressing staffing shortages and skill gaps is essential for optimising operational effectiveness and improving overall performance in waste management efforts. B1 noted that more training programmes are needed for staff to improve the waste management opportunities:

"I think there should be more training programmes for staff to enable us to update our skills. If the government is planning on investing in technology, then we should be prepared. Even if Government is planning on using some expatriates, it is still important we have first-hand knowledge regarding these technologies."

B2 explained that not only the provision of training but also financing the staffs are essential:

"I agree with the fact that more hands are needed because coverage areas have increased because of expansion and population growth but government cannot force contractors to employ more staff when most of them are complaining about funding due to non-compliance with payments."

He further added that:

"….the issue of lack of training of agency staff has to do with financing. It may not be a priority for the agencies at the moment".

The additional statement by B2 highlights the critical role of financial resources in addressing workforce training needs within waste management agencies. The mention of training being deprioritised due to financial constraints suggests competing priorities for allocating limited resources; this highlights the challenge of balancing budgetary considerations with the necessity of investing in staff development to enhance operational efficiency and effectiveness.

6.3.3.3. Inadequate Environmental Budgets

Further insights on the funding issue were attributed to waste management not being considered in budgets. Participant A1 expresses concern that government officials do not prioritise waste management as there is insufficient allocation directed to waste management initiatives. This lack of political will to address waste management appears to impact the extent to which initiatives that ensure effective waste management:

> *"I think there's a lack of concern about environmental issues among our politicians which reflects in the budgets for the sector. Allocations for waste management are barely sufficient for collection and disposal"* `

B1 agreed to the issue and opined that privatisation of waste services has provided some positive results, but a major emphasis from the governmental sector is required:

> *"Generally, I think the budgeting is done based on priorities and the government does not really see environmental issues as a top priority the way foreign governments do. The privatisation of service delivery has yielded some positive results but it doesn't mean government funding is not necessary."*

6.3.4. Natural Barriers

The experts highlighted flooding as the primary natural constraint. Urbanisation has been identified as a significant factor in exacerbating flooding events (Balogun et al., 2020). Urbanisation involves the development and expansion of cities, often replacing natural land cover with impervious surfaces such as roofs, roads, and pavements.

6.3.4.1 Flooding

Regarding the issue of flooding due to heavy rainfall, the experts highlighted how it impacts waste collection and exacerbates littering and dumping within the city. B5 put forward the concerns of flooding during the rainy season, which delays the process of waste collection:

> *"Areas like Gwarinpa are beginning to experience flooding during the rainy season, so it causes delays in waste collection because our vehicles are not able to assess such areas."*

Further to the discussion, A5 explained the growing concern of flooding is being experienced in different locations as well:

> *"I think the flooding we are experiencing in Abuja is contributing in spreading waste in most parts of the city."*

6.4. Discussion of Study Findings

This section provides a comprehensive discussion of the qualitative findings informed by the quantitative findings in Chapters Four and Five of this study. Guided by the research questions and literature review, the researcher explored the current state of waste management in Abuja to examine the challenges and barriers to SWM. Empirical evidence from the quantitative phase of this study showed that common waste management challenges in developing countries were also prevalent in the city. The challenges examined included variables within the study, such as waste collection, open dumping, recycling and segregation practices, information and communication on WM, willingness to pay for waste services, and public participation in waste management activities. The evidence was used to understand why these challenges exist by identifying the barriers to SWM in Abuja through FGDs with experts in the WM sector. A schematic diagram linking the challenges and the identified barriers is summarised in Figure 6.2. Thus, the following sections present comprehensive discussions on the challenges and barriers to SWM in Abuja.

6.4.1. Understanding the Challenges and Barriers to SWM in Abuja

Based on the analysis of the FDGs, four major categories of barriers were identified. These include Social and Economic, Regulatory and Strategy Deficits, Financial and Operational constraints, and Physical and Natural constraints. The following subsections discuss these barriers in the context of the current state of waste management in Abuja.

6.4.1.1. Social and Economic Barriers to SWM in Abuja

6.4.1.1.1. The Impacts of Population Increase and Urbanisation

Changes in population size can cause huge impacts on economic growth and put stress on the environment. The population explosion in Abuja poses significant challenges to the city‘s development and sustainability (Abubakar, 2019; Aliya, 2019; Kadafa, 2017). As discussed in Chapter Two of this study, a significant cause is rapid urbanisation, and a relative consequence is increased waste generation. With the population expanding from 1,406,239 to 3,564,126 between 2006 and 2016 (NBS, 2016), waste generation has become a pressing issue for waste management authorities. The findings in the waste generation analysis in this study in Chapter Five revealed that Abuja currently generates approximately 1,568 tonnes of waste daily, an increase of approximately 300% from the 492 tonnes reported by Ogwueleka in 2013.

According to one expert, it explains why districts such as Gudu and Gwarinpa, which are categorically lower-income and middle-income areas, pose challenges in waste management. Although there is no up-to-date data on the population breakdown of districts in the city, this argument is supported partially by the findings in the waste generation study in Chapter Five (see Table 5.1). Gudu and Gwarinpa districts were found to have more household occupants than the Maitama district (52, 56 and 45, respectively), suggesting a higher population density within the districts. However, the Gudu district generated the least waste during the 5-day study period, suggesting that waste management challenges in Gudu may not be primarily attributed to increasing waste quantities. Instead, the challenges may be linked to other factors, such as poor attitudes and behaviours towards waste disposal and management.

Another issue highlighted by the population surge is the proliferation of roadside sellers and unapproved stalls, particularly in high-density districts like Gwarinpa. It was explained that the activities of the informal traders exacerbate the challenge of open dumping, mainly because the sellers operate at night during the absence of regulatory and enforcement agents. This finding aligns with Adama's (2012) and Ahmed et al.

(2022) arguments on the challenges to waste management posed by the rise in economic activities in urban areas.

During the focus group discussions (FGDs), participants emphasised that waste collection delays in Abuja are influenced by the rapid population growth, which has resulted in increased traffic congestion in the city. This observation aligns with the findings of Ayantoyinbo and Adepoju (2018), who identified traffic as a significant barrier affecting solid waste transportation and logistics, particularly in urban areas. During peak hours, waste collection vehicles struggle to navigate through congested roads, leading to delays or cancellations of waste collection services. The frequent disruptions in the waste collection schedule result in the accumulation of waste and a littered environment. As revealed in the quantitative study, delays and obstructions in waste collection due to traffic congestion were also used to explain why approximately 32% of waste collection occurs at night.

6.4.1.1.2. The Impacts of an Uncontrolled Informal Sector

The presence of an uncontrolled informal sector in waste management presents both opportunities and challenges in Abuja. The quantitative study revealed that informal waste pickers play a crucial role in waste collection and recycling, contributing approximately 40% (see Figure 4.12) of waste collection in the city. The participants attributed their presence to the influx of people seeking employment, especially young men from neighbouring states. According to Ogwueleka and Naveen (2021), although scavengers contribute immensely to recycling and have registered an association called the Bola Association in Abuja, most of the people who run the association are illiterate and have no formal education, hindering their capacity to collaborate with waste agencies. However, one of the participants argues that most informal waste pickers operate in family-based networks or individually, making it challenging for waste management authorities to regulate their activities.

Participants highlighted that some waste pickers engage in illegal activities, contributing to problems such as littering and open dumping. According to the participants, waste pickers often search for valuable recyclables like plastic bottles, leading to the scattering of waste from bins during their scavenging activities. Despite the valid arguments raised by the experts, some authors have reported the issue of conflicts between the formal and informal sectors (Imam *et al*., 2008; Joseph *et al*., 2020). To clamp down on their activities in Abuja, waste pickers have faced bans within most parts of Abuja, and authorities set up by the municipality have seized their pushcarts. Their unhygienic and crude methods of operations make it more difficult for policymakers and waste agencies to adopt a more positive outlook (Oguntoyinbo, 2012).

However, one significant issue raised during the discussion was the impact of informal waste pickers on people‘s willingness to pay for waste management services. The quantitative results showed that only about 24% of the 343 respondents were either always or often willing to pay for waste services. According to experts in the FDGs, residents opt for the services of informal waste pickers due to lower charges or exchange arrangements for recyclables, which makes them less inclined to pay for formal waste services.

6.4.1.1.3. Lack of Environmental Education

Like in most developing countries like Togo, Benin, Angola, Burundi, Somalia, Zimbabwe, and Sudan, a significant barrier to sustainable waste management in Abuja is the lack of education programmes to foster awareness among the public (Debrah *et al*., 2022). The lack of education on waste management practices leads to poor waste disposal behaviours, including indiscriminate dumping and improper waste segregation. The participants highlighted that many individuals are unaware of the importance of waste segregation and recycling. Evidence from the quantitative survey supports this, as over half of the respondents do not practice recycling and segregation regularly (51% and 68%, respectively). Furthermore, the survey showed that despite 52% of the respondents having attained higher education, there was still a lack of awareness of all the elements of the waste hierarchy. This finding argues that the level of education does not necessarily translate to environmental knowledge. While formal education can equip individuals with general knowledge and critical thinking skills, it may not always cover specific topics like waste management comprehensively (Sinthumule & Mkumbuzi, 2019).

However, on the issues of segregation and recycling, one of the participants argued that there is a level of awareness among the public since people can segregate recyclables for economic benefits by selling recyclables to waste pickers. Nevertheless, some individuals may segregate recyclables primarily for financial reasons without understanding the environmental benefits or the broader waste management hierarchy. Hence, waste segregation for economic gain may not extend to other waste management practices, such as proper disposal of non-recyclable waste, particularly organic waste. Environmental education programs should target various age groups, including children in schools, to instil the importance of waste management from an early age.

6.4.1.1.4. The Impact of Poverty and Affordability

The eradication of poverty is a crucial step towards achieving sustainable development and improving people's well-being and quality of life worldwide. Particularly, Target 1.4 of Goal 1 emphasises that by 2030, all men and women, the poor and the vulnerable, should have equal rights to economic resources, as well as access to essential services, ownership, and control over land and other forms of property, inheritance, natural resources, appropriate new technology, and financial services (Loughnan *et al*., 2020). Nonetheless, in the review of literature in Chapter Two (see Section 2.4.3), Ezeah and Roberts (2012) and Kadafa (2017) identified that poverty and affordability present significant barriers to sustainable waste management in Abuja.

Similarly, a trivial trend supporting this argument was found in the quantitative study, which showed a statistically significant difference in willingness to pay among districts; mainly, respondents in Durunmi district (low-middle income) were less willing to pay than those in Gwarinpa (middle income). However, this interpretation is done with caution due to the small strength of the association. Most participants in the FGDs aligned with the findings and explained that economic hardships households face in the city may affect their willingness to pay for waste collection services. However, one of the experts argued that some high-income earners are also not willing to pay for waste services, as waste management may not be a top priority.

According to Adama (2012), in 1993, the AEPB introduced user charges for solid waste services in Abuja to commercialise the service due to inadequate finance. Tariffs for waste services are fixed primarily based on building types; hence, different areas have different chargers. The government expected privatisation to be funded mainly from these user charges. Although Adama raises the issue of the methods adopted by AEPB for fixing waste tariffs, the author did not investigate the relationship between the tariffs and consumer willingness to pay. However, the issue of affordability can be linked to households' level of patronage of the informal sector. Many informal waste pickers are willing to collect waste for a lower fee or even pay households for valuable recyclables; this incentivises households to engage with the informal sector, particularly when the formal waste collection services may be perceived as unaffordable or inadequately meeting their needs.

6.4.1.2. Regulatory and Strategy Barriers to SWM in Abuja

6.4.1.2.1. Ineffective Policies and Implementation

In Nigeria, National legislation provides the framework for all activities in the waste management sector, and the most significant legal basis for waste management remains the Federal Environmental Protection Agency (FEPA) Act (Abila & Kantola, 2013; Sridhar *et al.,* 2017). According to the Nigerian constitution adopted in 1999, waste management is one of the responsibilities assigned to the local government. The local government is entrusted with collecting and disposing waste, maintaining public convenience facilities, and managing sewage within its jurisdiction. As highlighted in Chapter Two of this study (see sections 2.4.2 & 2.8), one of the critical issues contributing to the inefficacy of waste management policies in Abuja is the lack of proper implementation and enforcement mechanisms (Ahmed *et al*., 2022).

During the FGDs, the participants argued that Nigeria needs cohesive waste management policies and effective implementation and enforcement strategies to tackle the challenges. They emphasised that existing policies are fragmented and complex to implement effectively, leading to inconsistent waste management practices. The experts noted the necessity for comprehensive waste management policies covering all aspects, from waste collection and disposal to recycling and energy recovery. They suggested that comprehensive data and research should inform policies and that evaluation and monitoring should focus on assessing policy effectiveness. Furthermore, the quantitative results indicated a lack of public interest as over half (52%) of the 343 respondents reported rarely participating in the Environmental Sanitation exercise. Aligning with these arguments, Danbaba *et al*.

(2016) noted that it is a quick-fix policy that lacks implementation and effectiveness. The study findings were affirmed by Olowoporopku (2017), who noted that despite implementing the sanitation program in Nigerian states, there is still a lack of citizen participation in the process.

Further to the issue of public participation, an OLR model was constructed to assess the influence of sociodemographic and economic factors that influence public participation in the sanitation exercise. The predictor variables were found to explain 25.7% of the variation in the outcome variable (see Table 4.14). Employment status and residential districts showed statistically significant ($p < .05$) influence on public participation in the sanitation exercise, given that all variables included in the model are constant. Interpretations suggest that the unemployed, civil servants, and residents in Maitama, Jabi and Gwarinpa districts were less likely to participate in sanitation than students and residents in Gudu district. The outcomes further the argument for the ineffectiveness of the policy. The implications may mean that the fixed day for the exercise does not favour the unemployed and civil servants, and based on the study classification of districts, participation reduces as income increases.

6.4.1.2.2. The Impact of Construction Activities

Nigeria's construction industry lacks policies (Ogunlolu *et al*., 2022). The relocation of the federal seat of authority from Lagos to Abuja in the 1980s triggered significant urban development and infrastructure expansion in the city (Abubakar, 2014). This transformation resulted in a surge of construction activities within Abuja, leading to increased construction waste generation, which poses a serious environmental threat and requires careful management to mitigate its negative impacts. The construction sector is notorious for generating substantial waste, including concrete, bricks, metals, wood, plastics, and other materials. Improper construction waste disposal can lead to environmental pollution, soil degradation, and water contamination (Albert *et al*., 2021). Additionally, the accumulation of construction debris can create unsightly and hazardous conditions in the urban landscape, affecting public health and safety.

During the FGDs, one of the participants brought attention to the careless dumping of construction waste by construction workers, which led to open dumping and littering in Abuja. This issue was emphasised as a significant concern, as it impacts waste management and influences public behaviour towards waste disposal. This observation aligns with the findings of Ogunlolu *et al*. (2022), who also highlighted the influence of improper construction waste disposal on public behaviour. Another issue raised by a participant was that construction workers often set up temporary living spaces close to project sites for convenience and easy access to their work. However, these makeshift settlements may lack proper facilities and infrastructure, leading to improper waste disposal practices. These workers may dump waste in nearby open spaces or water bodies, contributing to open dumping and littering.

Affordable housing is a significant problem in Abuja; therefore, given the slightest opportunity, people resort to low-cost options, sometimes temporary settlements in ongoing or abandoned construction sites (Abubakar, 2014). It was made known in the FGDs that these temporary settlements further complicate waste collection efforts for waste management authorities. The irregularity of such settlements and the transient nature of construction workers can make it difficult for waste collection services to effectively reach and manage waste from these areas. As a result, construction waste generated in these settlements may not be adequately collected and disposed of, leading to environmental pollution and health hazards.

Better planning and waste management practices at construction sites are needed to mitigate the impact of construction waste on waste management. Adequate arrangements for accommodating construction workers on-site during projects and proper waste disposal protocols can help minimise the adverse effects of construction activities on waste management.

6.4.1.2.3. Lack of Incentives

In developed countries, incentives have been employed as practical strategies to encourage citizens to participate in recycling and waste reduction initiatives (Smith *et al*., 2018; Johnson & Brown, 2019). These incentives motivate individuals and households to adopt environmentally friendly behaviours and contribute to sustainable waste management practices. In 2021, Nigeria's Lagos Waste Management Authority started a recycling initiative to promote proper waste disposal among residents. The campaign features creative slogans like ‘Turn your Cash into Trash‘ and ‘There is a Goldmine in your Dustbin‘ and has successfully motivated city dwellers and highlighted the financial benefits of recycling (World Bank, 2021). Through this campaign, the Lagos Waste Management Authority has sought to change the public's perception of waste from a burden to a potential source of income and environmental benefits. By reframing waste as a resource, the initiative empowers residents to take an active role in waste management and positively impact their environment.

On the contrary, in Abuja, the lack of incentives for waste recycling and segregation leads to poor waste management practices and low public participation in recycling efforts (Duru *et al*., 2019). Reflecting on the low recycling and segregation rates observed in the quantitative study, the experts in the FGDs agreed that there is a need to encourage waste management in Abuja to encourage these practices. These programs could include financial incentives, rewards, or recognition for individuals or communities actively participating in recycling and proper waste disposal. Policies need to be enhanced to drive the adoption of sustainable waste management practices.

6.4.1.3. Financial and Operational Barriers to SWM in Abuja

6.4.1.3.1. Inadequate Environmental Budgets

The literature review highlighted the effects of financial barriers to SWM (see section 2.4.1). Yukalang et al. (2017) state that limited financial resources and mismanagement of funds can severely impact waste management services, leading to inadequate coverage and lower service quality. Hence, the lack of adequate funding hampers the ability of waste management authorities to invest in modern waste collection infrastructure, recycling facilities, and WtE technologies.

Sufficient financial resources are critical for effectively functioning waste management agencies and organisations. Without adequate funding, these entities face numerous challenges in fulfilling their responsibilities and implementing sustainable waste management practices. One of the main consequences is the inability to expand waste collection services to cover all areas effectively. In low-income countries, collection alone drains up 80-90% of the MSWM budget (Kadafa, 2017). As the population grows and urbanisation accelerates, the demand for waste management services increases, putting further strain on already limited resources. As a result, some areas may be underserved or entirely left out of regular waste collection schedules, accumulating waste and potentially causing environmental and health hazards (Kadafa, 2017).

The experts discussed how waste management is often overlooked in budget allocation. They explained that insufficient funding is hampering the ability to invest in modern waste collection equipment, vehicles, and personnel. Inadequate infrastructure contributes to irregular waste collection schedules, leading to overflowing bins, illegal dumping, and littering, especially in highly populated areas.

6.4.1.3.2. The Impact of Infrastructural and Technical Deficits

As previously noted in the literature review in Chapter Two (refer to section 2.4), the lack of adequate waste management infrastructure is a significant barrier to sustainable waste management in developing countries (Ezeah & Roberts, 2012; Yukalang *et al*., 2017). The city's rapid population growth and urbanisation have outpaced the development of waste management facilities and services in many cities, leading to a shortfall in infrastructure to handle the increasing waste generation (Kadafa, 2017). One critical infrastructural challenge is the insufficient waste collection and disposal facilities to cater to the growing population. Inadequate waste collection points, transfer stations, and recycling centres result in inefficient waste collection and disposal processes (Hammed *et al*., 2016). Highlighting the importance of adequate infrastructure and technology in waste management, the participants explained that the lack of compactor vehicles, frequent breakdowns, and inadequate waste collection infrastructure cause delays in waste collection and disposal. Furthermore, it was noted that open trucks used for waste collection are not always suitable for specific areas, leading to further challenges in waste collection.

6.4.1.3.3. The Lack of Manpower and Skills

The challenge of insufficient staff in waste management agencies and contractors can have significant implications for waste management services in Abuja. With the city's rapid population growth and urbanisation, there is an increased demand for waste collection and disposal services. Insufficient staff can lead to delays in waste collection, disruptions in waste management schedules, and overwhelmed waste disposal facilities (Singh *et al.,* 2014).

Furthermore, the lack of necessary skills in waste management personnel can hinder the proper handling and treatment of different types of waste. The experts highlighted the challenge of insufficient staff and the lack of necessary skills in waste management agencies and contractors. The participants called for recruiting more waste management staff to meet the growing demand for waste collection and disposal services. Proper training programs were also suggested to equip waste workers with the necessary skills to handle waste management operations effectively.

6.4.1.4. Natural Barriers to SWM in Abuja

6.4.1.4.1. Flooding

Flooding was identified by Yukalang *et al*. (2017) as a barrier to SWM, especially in communities that are prone to floods. Impervious surfaces, such as concrete pavements and buildings, prevent rainwater from being absorbed into the ground. Instead, the water quickly runs off these surfaces and accumulates in stormwater drains and channels. With inadequate or poorly designed drainage systems, this runoff can overwhelm the existing infrastructure, leading to localised flooding. Furthermore, when heavy rainfall overwhelms drainage systems and causes flooding, water can pick up various types of waste and debris, including plastic bags, bottles, food wrappers, and other litter. According to the FGDs, flooding also affects waste collection and disposal operations, as vehicles cannot access certain areas during heavy rainfall; this aligns with the study by Umar *et al*. (2022), who reported flooding as a significant factor affecting SWM in Abuja. Furthermore, although not raised by the participants, the literature has reported that the Gosa landfill in Abuja closes yearly due to limited accessibility and other hazards caused by heavy rainfall (Ayuba *et al*., 2013; Nwosu *et al*., 2016).

6.5. Chapter Summary

This qualitative chapter aimed to identify the barriers hindering SWM in Abuja. Following the quantitative data analysis as a foundation for this study, two virtual sessions were held with stakeholders, including personnel from the Abuja Environmental Protection Board, private contractors, and local council representatives. Through these sessions, the study identified vital themes affecting waste management in the city: population increase and urbanisation, the unregulated informal sector, poverty and affordability, regulatory deficiencies, poor communication strategies, construction waste, lack of incentives, financial and operational constraints, and physical and natural constraints.

It was highlighted in the discussions how urbanisation has increased waste production and compounded traffic issues, hampering waste collection and how the informal sector plays a vital yet problematic role, as waste pickers often litter while searching for recyclables but offer cheaper services than formal waste management. Furthermore, the experts argued that poverty influences residents‘ willingness to pay for waste services, leading many to prefer these cheaper, informal services. The arguments extrapolated the need for more cohesive waste management policies and strategies and increased awareness through education and public participation. More robust communication strategies are required to address these issues.

Additionally, the lack of waste management on construction sites, poor incentives for proper waste management, operational constraints such as the non-availability of compactor vehicles, and insufficient staff present significant challenges. Overall, the findings point to the need for the government to create an environment that enables the implementation of WtE technologies. The next chapter will culminate the research findings and discuss the prospects of WtE in Abuja.

Chapter 7: Energy Recovery from Waste in Abuja: The Prospects

7.1. Introduction

The earlier chapters aimed to identify the barriers hindering Abuja's solid waste management (SWM). Building on quantitative data analysis, two virtual sessions were conducted with stakeholders, including Abuja Environmental Protection Board personnel, private contractors, and local council representatives. These discussions unveiled several key themes affecting waste management in the city: rapid population growth and urbanisation, an unregulated informal sector, poverty and affordability issues, regulatory deficiencies, poor communication strategies, construction waste challenges, lack of incentives, financial and operational constraints, and physical and natural barriers. Urbanisation has increased waste production and exacerbated traffic congestion, complicating waste collection efforts.

While offering more affordable waste services, the informal sector often exacerbates littering problems as waste pickers scatter refuse while searching for recyclables. Experts highlighted that poverty influences residents‘ ability to pay for formal waste services, driving reliance on cheaper informal options. The discussions underscored the necessity for cohesive waste management policies, enhanced public awareness through education and participation, and effective communication strategies. Significant challenges were identified in the lack of waste management on construction sites, poor incentives for proper waste disposal, and operational constraints like the shortage of compactor vehicles and insufficient staff. The findings emphasise the need for government intervention to create an enabling environment for implementing Waste-to-Energy (WtE) technologies.

Recently, global communities have been trying to achieve environmental sustainability and CE. The significance of SWM in achieving sustainable development is highlighted in various international development agendas, charters, and visions. One notable example is its support of several United Nations‘ sustainable development goals (SDGs). Sustainable SWM plays a crucial role in fulfilling SDG 6, which aims to ensure access to clean water and sanitation, as proper waste management prevents water pollution and contamination. Furthermore, it is also directly linked to SDG 11, which focuses on creating sustainable cities and inclusive communities. Therefore, effective waste management practices contribute to healthier and cleaner urban environments, promoting community well-being and enhancing the quality of life for city dwellers.

Energy is essential to societal development and is crucial in advancing global technology (Ogunjuyigbe *et al*., 2017). The availability and efficient utilisation of energy resources are fundamental for economic growth, social well-being, and environmental sustainability. The increasing energy demand, coupled with the need for sustainable and environmentally responsible solutions, has led to the exploration and development of renewable energy sources (Güney, 2019). Moreover, WtE has become attractive due to the sheer quantities of global waste. Rapid population growth and urbanisation have led to an exponential increase in waste production. According to the World Bank, global waste generation is expected to increase by 70% by 2050 (Ghosh, 2020). This alarming trend necessitates innovative solutions for waste management, particularly among developing countries in SSA (Ogunjuyigbe *et al*., 2017).

Waste-to-energy initiatives have the potential to contribute significantly to the achievement of SDGs 7 and 11. By harnessing the energy potential of waste materials, waste-to-energy technologies promote sustainable development, renewable energy generation, and efficient waste management practices. In addition, developing WtE technology is essential in addressing the issues related to landfill management and land disposal, Abuja's predominant waste disposal methods (Ogwueleka, 2013). By converting waste materials into usable energy, WtE technologies extend the lifespan of landfills and minimise the need to dedicate more land to waste disposal.

A draft report of the Nigerian National Policy on Solid Waste Management 2017 clearly outlines in Section 1.3 the government's interest in scaling up the introduction of WtE in the country (FEPA 2018). Although the draft policy does not indicate specific technologies being considered, the different technologies are generally reliant on SWM systems with adequate waste collection rates to ensure feedstock supply, knowledge of waste generation and composition statistics, and the presence of a well-established waste management infrastructure that supports waste collection, transportation, and treatment. Furthermore, a supportive regulatory environment and policies that encourage the development of WtE projects are crucial (Khan *et al*., 2022). The preceding chapters of this study have systematically brought attention to these matters. This discussion chapter aims to synthesise evidence from this research and literature to examine the prospects of implementing WtE technologies in Abuja. The chapter brings together the research by highlighting the viable WtE technology options in the context of the research findings and literature to address the last research question: **RQ5:** Is WtE viable in Abuja?

7.2. WtE Technology Options and Prospects for Abuja

Numerous studies reviewed in the literature have elucidated the sustainable aspects of WtE, emphasising its ability to reduce both the volume of MSW and contribute substantially to electricity generation (Ayodele*et al*., 2018; Nixon *et al.*, 2017; Nubi *et al*., 2022; Thomas & Soren, 2020). While some developing countries are introducing new WTE technologies on a regional or national scale, a lack of clear understanding regarding what is considered suitable and sustainable exists. Malav *et al*. (2020) reported that developing countries, such as India, have faced obstacles due to various factors in adopting WtE technologies.

These challenges include inadequate public involvement, absence of proper waste segregation, legal disputes, substandard waste materials, limited financial backing, and the lack of comprehensive policies. A specific example cited in their study and confirmed by Khan *et al*. (2020) is the failure of a 6 MW capacity WtE plant in Lucknow, India. Interestingly, the challenges highlighted by Malav *et al*. (2020) resonate with the waste management challenges in Abuja furthered in this study. The similarity in challenges between the two contexts showcases the universal nature of waste management difficulties in developing regions; this underscores the need for government intervention to address these barriers and create a supportive environment for successfully introducing WtE technologies.

According to Khan *et al*. (2022), policy development is a significant challenge for waste to energy in developing countries. The authors emphasised that open dumping would need to be controlled while policies focus on driving recycling and reuse. Similarly, Yan and Waluyo (2020) posited that implementing waste to energy in developing countries will require regulatory, technical and operational considerations. Furthermore, Alam *et al*. (2022), in their research on waste to energy for Chittagong in Bangladesh, identified technology, environment, social and economic factors as key criteria.

For technology selection, different technologies may be suitable for various waste types; therefore, the choice of WtE technologies must align with the specific waste composition and the region's needs (Khan *et al*., 2022); this means adapting technologies to local conditions and waste types is essential for successful implementation. Even so, the failure of the WtE plant in Lucknow further emphasises the need for careful consideration and planning when introducing WtE technologies.

In this study, the findings in Chapter Five (see Table 5.3) indicate that food/organic waste constitutes the most significant portion, approximately 46%, of the overall MSW composition in Abuja. This high percentage of organic waste is favourable because organic materials have the potential to generate biogas through AD. Biogas can be a renewable energy source for electricity generation, heating, and even vehicle fuel (Kaza & Bhada-Tata, 2018). Therefore, the significant presence of organic waste in the waste stream presents a promising opportunity for implementing biogas generation projects in Abuja to harness this clean energy source and reduce greenhouse gas emissions from waste decomposition in landfills. Nonetheless, it would be necessary to monitor possible changes in composition over time based on the indications of the declining organic components suggested in this study.

On the other hand, it was also determined that approximately 13% of the MSW composition in Abuja consists of paper components and another 13% comprises combined plastic components. These percentages suggest that paper and plastics are significant fractions of the waste stream. While biodegradable paper waste could be suitable for composting and biogas generation, non-biodegradable plastics and other fractions show potential for thermochemical combustion. Despite the significant presence of organic wastes in Abuja (Chapter Five), the findings from Chapter Six indicate a low level of knowledge about WtE, with participants advocating for increased awareness of waste management strategies generally. Increasing awareness of segregation and general waste management techniques, as advocated for by participants in the qualitative study, will provide the populace with the requisite information to implement sustainable practices. Employing the findings of chapters 5 and 6, policymakers may implement targeted interventions to address the waste management issues in Abuja, especially whilst having an idea of the extent/composition of waste.

From the reviewed literature in Chapter Two, among the WtE paths highlighted by researchers and various WtE guidance documents suitable for MSW with similar compositions to Abuja are AD, LFGR systems and incineration (Alao *et al*., 2021; Sridhar *et al*., 2019; UNEP, 2019). These conclusions were primarily based on technical, environmental, social and economic parameters using LCA and MCDA techniques. For example, Coelho and Lange (2018) focused on identifying sustainable waste management solutions for Rio de Janeiro, Brazil. They employed LCA methodology to assess the environmental impacts of different waste management options to achieve this. Their findings revealed that anaerobic digestion and recyclable recovery emerged as the city's most environmentally sustainable waste management approach.

In a Nigerian context, Ayodele *et al*. (2018) and Nubi *et al*. (2022) used an LCA in their economic and environmental assessment of electricity generation using biogas from an organic fraction of MSW for the cities of Ibadan and Abuja, respectively. Given the environmental parameters assessed, the authors concluded that AD is more viable than LFGR and incineration in both states. Similarly, MCDA methods were applied to a study by Alam *et al*. (2022) on selecting WtE technologies based on technical, economic, environmental, and social issues in Bangladesh. Using the AHP method, their study ranked AD as the most suitable technology ahead of LFGR and incineration.

Kaza and Bhada-Tata (2018) point out that emerging WtE technologies like pyrolysis and gasification are often not considered due to their higher technical requirements and the need for more homogenous waste types. Additionally, these technologies have not yet been fully proven at a large scale for treating MSW, even in advanced countries. With less attention to the environmental impacts of incineration, Nigeria's interest in WtE technologies seems to be driven by its potential for waste reduction and electricity generation. These two factors are key drivers that make WtE solutions attractive for the country‘s sustainable waste management and energy needs, and this explains why researchers in Nigeria tend to focus on incineration and energy recovery potentials. The following subsections highlight the energy recovery potential of the identified technologies.

7.3. Energy Recovery Potentials from WtE Technologies

The literature review on WtE potentials in Nigeria showed that most studies focus on incineration. While WtE technologies such as anaerobic digestion, gasification, and pyrolysis continue to gain recognition for their environmental advantages, incineration still dominates as the most used method worldwide. The primary reasons for its widespread adoption are its energy generation capability and its effectiveness in reducing the volume of waste, making it attractive to developing countries (UNEP, 2019). During the qualitative study in Chapter Five, participants mentioned incineration as an alternate method of waste disposal, indicating corroboration of the findings from the literature review conducted.

This method appeared to be popular as compared to other modern technologies. Hence, there seems to be a unanimous call for increased awareness. However, a primary technical concern for incineration in developing countries is the high moisture content, which yields a low calorific value (CV) of MSW, making it unsuitable for thermal technologies (UNEP, 2019). When the waste stream‘s moisture content rises, its calorific value begins to decrease due to the latent heat of vaporisation (Kumar & Samadder, 2017). These issues further the argument favouring biological conversion technologies like AD and LFGR in countries with high moisture content. However, it was reported by Aderoju *et al*. (2019) and AEPB (2020) that the average moisture content of MSW in Abuja is about 28%, and the average CV is approximately 18 MJ/kg, noting that it may be suitable for harnessing energy.

The electricity generation potential is a crucial technical criterion for selecting the most suitable WtE technology among various alternatives (Alao *et al*., 2020). Various researchers have investigated the electricity generation potential from MSW in Nigeria (Alao *et al*., 2020; Somorin *et al*., 2017; Ogunjuyibe et al., 2017; Olujobi *et al*., 2021). One such study was comprehensive research by Ogunjuyibe *et al*. (2017) on the electricity generation potential of MSW in different Nigerian cities, comparing incineration, LFGR and AD. Compared to this present study, the waste composition assessment by Ogunjuyibe and his colleagues for their analysis showed similar patterns and similar waste fractions for food, paper and plastics, which were the key components. In their study, these three components were combined to analyse the energy potentials for incineration and LFGR, while only the food fraction was utilised to assess AD.

The results presented by Ogunjuyibe *et al*. (2017) estimated that in Abuja, the electricity generation potentials for LFGR, incineration and AD to be 112.6GWh, 53.8GWh and 125.7GWh per annum respectively. While these results agreed with the findings of Nubi *et al*. (2022), that AD has a higher electricity generation potential than incineration in Abuja, and point to the fact that a potentially high amount of energy that can be recovered using these technologies, the estimated potentials may have been underreported. Using population forecasting methods, the authors projected that Abuja would generate approximately 243,155 tons/yr in 2021.

Based on the findings of this research, it is estimated that approximately 1,568 tons/day of MSW was generated in the city, amounting to 572,320 tons/yr. This implies that MSW in Abuja may have the capacity to generate more than double the energy potentials for each of the technologies assessed and earlier reported by Ogunjuyibe *et al*. (2017). This highlights the substantial potential for energy recovery from MSW in Abuja and emphasises the importance of further exploring and maximising the use of WtE technologies to harness this valuable energy resource.

On the issue of high moisture content, an example was highlighted in Chapter Two (see section 2.11.2), where Zhao *et al*. (2016) reported a similar situation in China, where the waste composition also contains a high proportion of food waste with low calorific value and high moisture content, common characteristics in other developing countries. To address this issue, China has developed innovative circulating fluidised bed-based incineration plants, with 28 currently operational plants processing 800 tonnes/d of MSW and successfully generating electricity (World Energy Resources, 2016). These advanced incineration technologies have effectively tackled the challenges posed by high moisture content in the waste, ensuring efficient energy conversion and waste management. Countries like Nigeria can adopt them. Furthermore, incineration is advantageous due to its thermochemical conversion process, enabling the utilisation of all organic matter, whether biodegradable or non-biodegradable, for energy production. This feature allows incineration to efficiently process diverse waste streams, making it a flexible and applicable option in various waste management situations.

7.4. Is WtE Viable in Abuja?

The previous sections show that WtE technologies offer a promising solution to address Nigeria's pressing waste management challenges while contributing to sustainable energy production. The country's abundant waste resources provide a substantial feedstock for energy production. With a vast quantity of organic waste generated daily, there is significant potential for biogas production through anaerobic digestion. Additionally, the high proportion of plastics and other combustible materials in the waste stream makes gasification and incineration viable options for energy recovery. Furthermore, WtE technologies align with Nigeria's commitment to mitigating climate change and reducing greenhouse gas emissions.

While the technical feasibility and environmental benefits of WtE are evident, successfully implementing these technologies requires overcoming several challenges. These include inadequate waste collection and segregation infrastructure, a lack of public awareness and understanding of WtE, and financial constraints for establishing and operating WtE plants. Policies and regulations must also be strengthened to create a conducive environment for WtE investments and operations.

No WtE technology can meet all criteria, local constraints, and waste types. The multifaceted aspects of waste management create a complex challenge when selecting an appropriate energy conversion option (Alao *et al*., 2020). Thus, it is necessary to achieve a consensus among multiple and often conflicting priorities (Kaza & Bhada-Tata, 2018). Although technical considerations such as waste composition and generation are critical to decisions on suitable technologies, researchers have involved economic, environmental, and social criteria in the waste management problems in the forms of the three renowned sustainability pillars (Torkayesh *et al*., 2022). Each of these dimensions interplays, making the decision-making process intricate and complex.

The literature review determined that in waste management, two prominent techniques used for WtE selection are Multiple-Criteria Decision Analysis (MCDA) and Life Cycle Assessment (LCA). Both methodologies play essential roles in evaluating the feasibility and environmental impacts of converting waste into energy by approaching the assessment from distinct perspectives.

The MCDA decision-making tool considers multiple criteria and objectives to assess WTE technologies. It offers a structured and systematic approach to decision-making, allowing stakeholders to select the most suitable waste treatment technologies, landfill locations, and waste treatment plant locations based on multiple criteria and considerations (Torkayesh *et al*., 2022). It involves identifying and weighing environmental impact, economic viability, social acceptance, technological maturity, and regulatory compliance. Therefore, stakeholders can assign relative importance to these criteria based on their preferences and priorities. By employing MCDA, decision-makers can rank and compare various WTE options, leading to an informed and comprehensive decision-making process. As noted in Chapter Two, Torkayesh *et al*. (2022) established that the Analytic Hierarchy Process (AHP) is the most common method of MCDA employed in waste management studies. Its advantage lies in its ability to incorporate subjective preferences and diverse stakeholder perspectives, resulting in a more inclusive evaluation (Garfi *et al*., 2009; Sharma *et al*., 2015).

On the other hand, LCA is an analytical methodology that evaluates the environmental impacts of WtE technologies throughout their entire life cycle – from raw material extraction and manufacturing to operation, maintenance, and end-of-life disposal. It considers various environmental indicators, such as greenhouse gas emissions, energy consumption, air and water pollution, and resource depletion (Yadav & Sammander, 2022). Researchers have employed it to provide a holistic understanding of the environmental implications associated with each WTE option, thereby allowing decision-makers to identify potential hotspots in the life cycle of each technology and enabling them to focus on mitigating the most significant environmental impacts.

Overall, the findings from various studies utilising both LCA and MCDA methods suggest that biological conversion methods are more suitable than incineration for waste management in developing countries like Nigeria. These studies compared parameters on the environmental impacts and multi-dimensional aspects of WtE technologies, indicating that biological conversion methods, particularly AD, offer more sustainable and socially acceptable solutions. However, in most cases, from an energy generation perspective, the focus turns to incineration with optimised combustion (UNEP, 2019).

The arguments Ogunjuyibe et al. (2017) presented based on techno-economic parameters, such as AD being preferable to LFGR and incineration in Abuja, would require further assessments. Considering the complexity of WM in Nigeria, more parameters would be necessary to inform a comprehensive decision. It has been argued that in developing countries, the social impact assessments of projects are often overlooked compared to their technical and economic impacts (Khan *et al*., 2022). While the technical and environmental benefits of WtE are well-established, a country's socio-political landscape can significantly impact the adoption and implementation of WtE technologies.

Despite the benefits and potential of MCDA as a comprehensive sustainability assessment tool, its application in waste management research within SSA countries, including Nigeria, has been limited. Vlachokostas *et al*. (2020) highlighted the scarcity of MCDA studies in SSA countries, primarily due to the lack of reliable data and the slow adoption of the decision-making technique. The authors blamed the dearth of MCDA studies for the delays or suspensions of WtE projects, as insufficient information and assessment tools hamper crucial decision-making processes. Despite these challenges, Nigeria has to adopt a comprehensive assessment method in its decision-making process. A holistic approach is essential to maximise the viability of WtE in Nigeria; this involves fostering collaboration between the government, private sector, and local communities to develop ISWM systems incorporating WtE technologies.

7.5. Chapter Summary

This chapter has illuminated the intricate interplay between waste management challenges, technological possibilities, and socio-economic dynamics by aligning research outcomes with established knowledge. By interweaving the practical realities gathered from the study with the existing body of literature, a nuanced perspective has emerged that underscores both the promise and the complexities of introducing Waste-to-Energy (WtE) solutions in Abuja. This chapter critically analyses the current waste management infrastructure, identifies the technological advancements that can be leveraged, and examines the socio-economic factors that influence the adoption and implementation of WtE technologies. The synthesis of these elements reveals a comprehensive understanding of how WtE can address the city's waste management issues while contributing to sustainable energy production.

The culmination of this chapter captures a holistic picture that underscores the multifaceted dimensions of WtE development. It bridges the gap between theoretical propositions and empirical realities, providing a coherent narrative that navigates the path from current challenges to potential solutions. By highlighting the interconnectedness of waste management practices, technological innovations, and socio-economic considerations, this chapter plays a crucial role in shaping a roadmap for stakeholders, empowering them to make informed decisions, engage in strategic planning, and develop policies that leverage the transformative potential of WtE. This integrative approach enhances the feasibility of implementing WtE projects in Abuja and ensures that these projects are sustainable, socially acceptable, and economically viable. As we move to the next chapter, which will present the conclusion and recommendations, the insights gained here lay a strong foundation for actionable steps towards achieving sustainable waste management and energy generation in Abuja.

Chapter 8: Conclusions and Recommendations

8.1. Introduction

This chapter provides an overview of the general conclusions and recommendations derived from the research. It begins by offering a synopsis of the research process. Then, it summarises the findings, demonstrating how the research aim and questions were accomplished. The following section highlights the study's key contributions to the existing body of knowledge. Lastly, the chapter puts forth several recommendations intended for industry practitioners and policymakers to address the prospects of WtE technologies in Abuja, Nigeria.

8.2. Review of the Research Process

This research examined the current state of waste management in Abuja and its interest in implementing waste-to-energy technologies. The complex and broad nature of the inquiry required multiple data sources integrated to achieve the study aim. Therefore, the research followed a comprehensive approach that involved a literature review, data collection through surveys and focus group discussions, data analysis, and synthesis of results. The researcher began by reviewing the literature on waste management from a global perspective before focusing on the study area, Nigeria's capital city, Abuja. The review indicated prevalent challenges and barriers to sustainable waste management, mainly in developing countries.

A sequential explanatory design was then set in motion for the investigation. Firstly, a survey instrument was constructed to explore the current state of waste management in the city and provide empirical evidence. A waste audit process backed this up to complete the first phase of data collection. The results from the first phase provided the foundation for the second phase, which identified the barriers to sustainable waste management in Abuja through FGDs with operations experts in the industry. The study achieved its aim by integrating data from various sources to determine the prospects of implementing waste-to-energy technologies in Abuja. The answer to each research question is detailed in the following sections.

8.3. Summary of Research Questions and Conclusions

8.3.1. RQ1: What is the current state of Waste Management in Abuja?

The literature review conducted in this study shed light on the various challenges faced in achieving sustainable waste management in developing countries, particularly in rapidly urbanising areas like Abuja. To better understand the current state of waste management in Abuja, the research employed quantitative research methods, using a survey instrument developed based on the challenges identified in the literature. Stratification and random sampling ensured that all socioeconomic sub-groups within the city were captured, representing the general populace fairly.

The survey results highlighted in Chapter 4, Section 4.6, revealed that Abuja, despite being a planned capital city, faces challenges similar to those faced by other developing cities. The active involvement of the informal sector in waste collection indicated a lack of coordination and inefficiency on the part of responsible agencies. Open waste dumping was also observed to be an ongoing problem within the city (see subsection 4.6.4 in Chapter 4). Additionally, the survey found that most residents were reluctant to pay for waste services, and there was a lack of participation in recycling or waste segregation at the source (see subsections 4.6.3 and 4.6.6 in Chapter 4).

Moreover, inadequate information and communication on waste-related matters were evident, further hindering effective waste management practices (see subsection 4.6.5). Another important aspect is that even though the environmental sanitation exercise is legally mandated in Abuja, the survey results revealed a poor attitude towards participation among residents (see subsection 4.6.7). These findings suggest that Abuja still has waste management challenges similar to other cities in developing countries, as discussed in the literature review in Chapter 2. A more in-depth understanding of why these challenges are prevalent in Abuja is addressed in RQ4.

8.3.2. RQ2: What sociodemographic and economic factors influence public participation in environmental sanitation in Abuja?

In an attempt to answer the second research question, the literature review approach was also employed. The literature review established that the environmental sanitation exercise is a government strategy in Nigeria aimed at improving waste management practices within communities (Section 2.9, Table 2.3). However, it was reported that there has been a poor public response regarding active involvement in the strategy since its implementation. While no previous literature specifically investigated the influence of sociodemographic and economic factors on the environmental exercise in Nigeria, the general literature on waste management and environmental strategies indicated that public participation can be influenced by factors such as gender, education, employment status, cultural norms, and income (subsection 2.10.1).

The researcher assessed these sociodemographic and economic factors using an Ordinal Logistic Regression (OLR) model to fill this gap. The findings from the OLR model discussed in Chapter 4, subsection 4.6.7, suggest that employment and income levels influence participation in the sanitation exercise. Overall, participation in the exercise was found to be low among respondents. However, after controlling for all variables in the model, it was observed that the unemployed and civil servants were less likely to participate in the exercise. Moreover, there was a tendency for participation to decrease as income levels increased.

Based on these findings, the research effectively addressed the research question by identifying the factors influencing public participation in the environmental sanitation exercise in Nigeria. The results highlight the importance of considering sociodemographic and economic factors when designing waste management and environmental strategies to encourage higher levels of public participation.

8.3.3. RQ3: What is the current estimated per capita waste generation and the daily amount of waste generated in Abuja?

As highlighted in Section 2.4 of the literature review, a significant challenge in Nigeria‘s waste management system is the absence of a reliable and comprehensive database of waste quantities. Where data is available, discrepancies often arise due to researchers' varied methods, leading to inconsistencies and inaccuracies. To address this issue in the present study, a rigorous waste quantification method was applied using a door-to-door waste sampling technique.

The study was conducted across three districts in Abuja, Nigeria: Gudu (representing a low-income area), Gwarinpa (middle-income), and Maitama (high-income). These districts were selected through a stratified random sampling method to ensure that a diverse socioeconomic spectrum was represented. Over five days, 120 waste samples were collected from 24 households, generating 498 kg of municipal solid waste (MSW). Based on this data, the study calculated a per capita waste generation rate of 0.66 kg/capita/day. Extrapolating from this, the estimated daily waste generation for the entire city was determined to be 1,568 tons, based on the population figures available at the time of the study.

8.3.4. RQ4: Does socioeconomic status influence waste generation and composition in Abuja?

Chapter 2, section 2.6, explores the influence of socioeconomic status on waste generation and composition. However, it is suggested that these factors can vary significantly across different geographical regions, indicating that local context plays a crucial role in shaping waste patterns and management needs. Based on the stratified random sampling into the three socio-economic groups, the results in this study revealed that socioeconomic status plays a critical role in determining the quantity and composition of waste in Abuja. Specifically, the low-income district generated significantly different amounts of waste than the middle- and high-income districts. Moreover, the influence of socioeconomic status extended to the composition of waste, where marked differences were noted across all waste fractions except wood. Organic waste was more dominant in the high-income group. These differences may be due to the higher purchasing power of high-income people. The findings from this study suggest the need for tailored waste management strategies that account for the socioeconomic variations in waste generation and composition.

8.3.5. RQ5: What are the barriers to sustainable waste management in Abuja?

The study's findings addressing RQ1 were synthesised and combined with literature to provide the foundation for developing the FGD agenda to address RQ5. Hence, experts in the sector were recruited to understand why these challenges existed by identifying the barriers to sustainable waste management in Abuja. Among the barriers linked to the difficulties were “lack of incentives”, “inadequate policies” and “strategies”, social constraints due to the “unregulated informal sector”, “rapid population increase”, barriers related to finance and operations like “inadequate environmental budgets”, “lack of infrastructure”, and natural barriers like “flooding”. It was also induced during the discussions on how construction activities impact waste management in Abuja. Overall, 12 barriers were identified by the experts (see Figure 6.1). The effect of these barriers on waste management in Abuja is widely discussed in section 6.4. Recommendations on how to overcome these barriers are highlighted in section 8.4 of this chapter.

8.3.6. RQ6: Is WtE Viable in Abuja?

A synthesis of the results from the broad mixed-method approach employed in this study indicates that Abuja has the potential to adopt Waste-to-Energy (WtE) as part of its waste management strategy. While the findings in Chapter 4 reveal that Abuja is currently grappling with waste management issues such as low collection rates and inadequate recycling and segregation practices, which could hinder the efficiency of Waste-to-Energy (WtE) operations, Chapter 5 contends that the city produces sufficient waste to support specific WtE technologies; this suggests that, despite existing challenges, there is potential for WtE in Abuja, provided that improvements are made in waste handling, segregation, and infrastructure to optimise the flow and quality of waste for energy conversion.

Furthermore, the barriers identified in the quantitative study in Chapter 6 highlight key areas where government intervention can enhance the viability of Waste-to-Energy (WtE) in Abuja. These barriers include inadequate infrastructure, insufficient funding, lack of regulatory frameworks, and limited public awareness. Addressing these issues through targeted policies, investment in waste management infrastructure, and public education initiatives could significantly improve waste collection, segregation, and recycling, creating a more favourable environment for successfully implementing WtE technologies.

The following section provides a detailed discussion of tailored recommendations derived from the comprehensive analysis of the research findings. These recommendations aim to address the identified challenges and capitalise on the opportunities for improving waste management and Waste-to-Energy (WtE) viability in Abuja.

8.4. Recommendations

8.4.1. Recommendations Towards Sustainable Waste Management in Abuja

The findings of this study have shed light on challenges and barriers associated with waste management in Abuja and highlighted the need for effective measures to promote sustainable waste practices in the city. Based on the results and insights gained from the research, several recommendations have been formulated to address these challenges and enhance waste management strategies in Abuja. The following subsections present the recommendations in detail, with each subheading of recommendations interweaving why these recommendations are suggested and concluding with how these may be achieved.

8.4.1.1. Strengthening Policy, Regulations and Strategies

An essential step in pursuing sustainable waste management in Abuja is the establishment of comprehensive and enforceable waste management policies and regulations; this is principally recommended based on the findings from the qualitative study reported in section 6.3.2.1. Participants in the study highlighted a lack of effective policies that are also regularly monitored and evaluated. Additionally, this recommendation is based on the findings from the literature published by Ganda (2020) and Hoinaru *et al*. (2020). By crafting a comprehensive framework that encompasses all facets of waste handling, from collection to disposal, the city can lay a strong foundation for sustainable waste practices. These policies should be benchmarked against global best practices while tailoring them to meet the specific demands of the city. Formulating specific waste management standards and targets for various sectors is pivotal to ensuring adherence to sustainable practices. Furthermore, participants in the study highlighted how nepotism and favouritism impact the enforcement of waste management regulations; this necessitates implementing monitoring systems to ensure that enforcement is achieved when waste management policies are contravened.

While the environmental sanitation strategy may have helped ensure cleanliness, it also presents an opportunity to promote recycling and source segregation. Introducing incentives for recycling initiatives becomes imperative to bolster recycling efforts.

Measures such as tax incentives or monetary rewards for individuals and businesses that actively engage in recycling will elevate recycling rates and divert substantial waste away from landfills, contributing to resource conservation.

Based on the findings from the qualitative study in this thesis, participants advocate for intensive education on waste management using mass media, internet technology and inclusion into school curriculums. Public awareness campaigns are a powerful tool to educate residents about the significance of sustainable waste management. These campaigns should encourage citizens to adopt responsible waste disposal practices, segregate recyclable materials, and minimise waste generation. Public engagement and education can be pivotal in shaping a waste-conscious community. Adequate dissemination of information and communication about waste management practices will help to expand their coverage. New means of communication, like social media, should be considered.

Likewise, authorities need to institute a culture of waste segregation at the source. It is crucial to mandate that residents and businesses separate recyclable materials from non-recyclable waste. In tandem, robust enforcement mechanisms must be in place to discourage illegal dumping and improper waste disposal. Imposing fines and penalties for violations can serve as a strong deterrent and ensure compliance with waste management regulations.

Additionally, regular and rigorous monitoring and evaluation of progress are essential components of an effective waste management strategy. This ongoing assessment allows the city to make informed decisions, effect necessary adjustments, and enhance the overall efficiency of waste management practices. By consistently evaluating outcomes against set targets, Abuja can continuously refine its waste management approach and steer it toward a more sustainable and successful trajectory.

8.4.1.2. Promoting Multi-Stakeholder Collaboration via an ISWM System

Adopting an integrated solid waste management (ISWM) framework is a crucial pathway towards sustainable solutions to address the intricate challenges of waste management in developing countries like Nigeria. ISWM is a comprehensive approach emphasising the harmonious collaboration of various stakeholders, including the informal sector, experts, private sector entities, and local communities. This collective effort aims to holistically manage the entire waste lifecycle, from generation and collection to transportation, treatment, and safe disposal. By convening diverse stakeholders within these committees, Abuja can harness the collective expertise of participants, fostering a cooperative environment conducive to generating effective and adaptable waste management strategies. Such collaborative platforms can be pivotal in formulating and implementing policies addressing the diverse challenges of waste management.

Furthermore, the ISWM approach underscores the significance of public engagement and participation. Initiatives such as town hall meetings, workshops, and awareness campaigns are vital components of this strategy. By actively involving residents and community members in these activities, Abuja can ensure that the local population understands and embraces its waste management policies and regulations. This participation would cultivate a sense of shared ownership and accountability, ultimately driving the adoption of sustainable waste practices at the grassroots level.

8.4.1.3. Finance and Investments

In waste management transformation, the role of finance and investments emerges as a pivotal factor for success. Despite the progress made through integrating PPPs into the waste management system in Abuja, the government needs to show continuous support through financial commitments. Adequate allocation of environmental budgets to bolster essential waste management infrastructure is indispensable in driving sustainable practices and achieving meaningful outcomes. This recommendation underlines the significance of directing financial resources towards developing and enhancing critical facilities, including recycling and waste transfer within the city.

Modernising waste collection and disposal infrastructure is a cornerstone in elevating the efficiency and effectiveness of waste management activities. Hence, by channelling financial investments into upgrading these vital components, Abuja can streamline waste collection processes, optimise resource utilisation, and foster a more significant recovery of valuable materials; this contributes to improved waste diversion and reduction and paves the way for enhanced environmental stewardship.

Furthermore, robust financial commitments are integral to the successful implementation of advanced WtE technologies, which have the potential to yield multiple benefits, including energy generation and waste volume reduction. Allocating resources for establishing and operating such facilities showcases a forward-looking approach to waste management, aligning with global trends that emphasise sustainable resource utilisation and renewable energy production.

8.4.1.4. Research and Data Management

Consistent and systematic monitoring and evaluation of waste management practices play a pivotal role in gauging the success of implemented policies. By scrutinizing data related to waste generation, collection rates, recycling efficiency, and pertinent metrics, valuable insights can be gleaned to guide future enhancements. The dynamic population shifts in Abuja may underscore the importance of cross-sectional studies over longitudinal ones. This approach facilitates establishing a comprehensive waste data management system that effectively tracks waste generation, composition, and collection trends. Such data is a cornerstone for informed decision-making, policy shaping, and resource allocation.

Furthermore, creating an accessible and robust database is imperative to bolster research efforts in this domain. This database would serve as a central repository, housing valuable information related to waste management practices, trends, and outcomes; this would facilitate easy access to pertinent data for researchers and policymakers and encourage collaboration, knowledge sharing, and evidence-based decision-making.

8.4.2. Recommendations Towards Adopting WtE Technologies

In developing nations like Nigeria, where fragile waste management systems encompass institutional frameworks and legal architectures, an assertive promotion of cutting-edge technologies could inadvertently trigger adverse consequences for the overarching evolution of waste management practices. While innovative methods such as AD, incineration, and LFGR exhibit promising technical attributes, it remains imperative to factor in a broader spectrum of considerations. Elements encompassing economic viability, environmental impacts, and social implications demand thorough scrutiny before embracing any particular technology. As such, it is strongly recommended that governmental bodies adopt a comprehensive and inclusive approach to evaluation, fortified by diligent research when making pivotal decisions. MCDA techniques offer a potent avenue for a comprehensive assessment of the diverse technological options, thus enabling informed and well-balanced choices.

Moreover, as part of the transition strategy, alternative initiatives warrant exploration to integrate advanced waste management technologies. One promising avenue deserving of in-depth exploration is the deliberate cultivation of composting practices. Although composting might not directly translate into electricity generation, a central tenet driving waste management in Nigeria, its potential significance extends beyond the immediate scope of energy recovery.

While this research, grounded in its focus on electricity generation, has not comprehensively delved into composting, the practice holds inherent value. Composting is a sustainable mechanism for organic waste management, aligning seamlessly with the principles of CE and environmental stewardship. By diverting organic waste from landfills and harnessing its potential to enrich soil quality and support agriculture, composting can substantially contribute to waste reduction and environmental sustainability.

In essence, promoting composting serves two purposes. First, it can tackle the pressing concern of organic waste management, ameliorating landfill strain and curbing associated environmental challenges. Second, it would lay the groundwork for cultivating a waste-conscious society primed for more advanced waste management technologies in the long run. Hence, composting can serve as a strategic precursor, fostering a foundation of sustainability that harmonises with the aspirations of Nigeria's waste management landscape.

8.5. Contributions to Knowledge and Practice

This research contributes to theoretical frameworks and practical insights within Nigeria's waste management area. Theoretically, it delves into the intricate interplay of socio-economic dynamics, waste composition, and technological viability, enriching our understanding of how these factors coalesce to shape effective waste management strategies.

Moreover, this study propels the discourse on waste management beyond the confines of academia, offering pragmatic insights that resonate with real-world challenges. By unravelling the complex web of barriers and opportunities in waste management practices, this research provides a compass for policymakers, urban planners, and practitioners navigating the multifaceted landscape of waste management in developing contexts like Abuja. Key contributions to knowledge are summarised as follows:

1. Using an explanatory sequential design of quantitative and qualitative methods, this research establishes that waste management challenges in Abuja will likely hinder the introduction of WtE technologies in the city. Furthermore, industry experts identified 12 barriers to SWM in the study area.
2. It was established that, as of the study's date, approximately 0.66kg/capita/day of MSW is generated in Abuja, resulting in more waste than previously reported.

In terms of practical application, the recommendations stemming from this study crystallise into actionable strategies for policymakers and stakeholders. The advocacy for robust policies, multi-stakeholder collaboration, and data-driven decision-making offers a blueprint for orchestrating sustainable waste management practices. Also, this study's findings on public participation in environmental sanitation show the importance of social considerations in policy development and implementation. Additionally, the emphasis on accurate, comprehensive waste data management underpins the creation of a knowledge repository that empowers future waste management initiatives with informed choices and adaptive strategies. This research extends the boundaries of waste management research while delivering pragmatic insights that can foster tangible improvements in waste management practices. Bridging theory and practice emerges as a vital compass guiding the trajectory of waste management activities, particularly in the dynamic context of Abuja and similar developing urban cities.

8.6. Study Limitations

While this research has yielded valuable insights into the current state of waste management in Abuja, it is essential to acknowledge the limitations that might have influenced the scope, validity, and overall quality of this study. These limitations highlighted within this discussion are crucial for comprehensively understanding the research context.

1. The study‘s cross-sectional design provides a snapshot of Abuja's waste management situation at a specific time, which worked best considering the time allocated for the research.

2. A major external factor relating to available time is that this study was affected by the COVID-19 pandemic that started in early 2020; this resulted in international and local travel restrictions, causing data collection delays. Hence, the allocated time for the research was significantly reduced. In light of this, the intended methods for data collection had to be realigned. One significant change was in the survey administration, which changed from face-to-face delivery to online; this impacted the socioeconomic stratification based on residential building types, which would have been more evident from face-to-face if the researcher had been able to survey the study area practically, although empirical evidence confirmed the trend. However, the stratification was validated during the waste composition study after restrictions had been lifted, and the researcher could select participants by visiting the districts and physically observing building types.

3. The selection of study areas and participants might not fully capture the diversity and heterogeneity of waste management practices across all districts of Abuja. A more extensive and diverse sample could further enhance the generalisability of the findings. It is also important to note that Abuja‘s unique socio-economic, cultural, and political context might limit the generalizability of findings to other cities or regions. The researcher also acknowledges that beyond the Abuja metropolis, there are lower-income dwellers who are not captured in the study. Hence, the stratification is based only on those residents within the study area. Within the borders of Nigeria, factors specific to Abuja could influence waste management practices and outcomes differently elsewhere.

4. It is also worth noting that the pandemic may have impacted the waste generation rates and composition during this study. The changes in consumption patterns, increased use of single-use items, and shifts in lifestyle behaviours resulting from the pandemic could affect the waste management landscape. Also, seasonal variation was not considered during the study; however, there was no rainfall.

5. While the researcher considered and recommended appropriations on the issue of social desirability bias through self-reporting, it is still possible that some of the information from respondents may include bias. Likewise, while valuable, the study's engagement with waste management stakeholders might not encompass the entire spectrum of relevant actors and perspectives. It is also assumed that not all the barriers have been identified. A more comprehensive engagement approach could provide a more holistic understanding of barriers and opportunities.

6. The techno-economic feasibility assessment of WtE technologies is based on existing literature. It might not fully capture site-specific conditions in Abuja, potentially affecting the accuracy of potential energy recovery estimates. Furthermore, limited access to comprehensive and up-to-date waste-related data might have underrepresented certain aspects of waste management.

7. Lastly, socio-economic and environmental conditions and policy dynamics might have evolved since the study's data collection. Hence, these changes could influence the current state of waste management in Abuja.

8.7. Future Research

This research evaluated Abuja's current waste management situation in relation to introducing WtE technologies. The findings have informed several aspects of waste management in Abuja. The outcomes hold significant implications for policy and practice, opening avenues for further exploration and refinement. To this end, the following recommendations for future research emerge.

1. Future studies can delve deeper into the socio-economic factors influencing waste generation and composition in Abuja. Comprehensive research investigating how cultural norms, education levels, and income distribution

interplay with waste behaviours and consumption patterns could provide nuanced insights.

2. While this present study can serve as a baseline cross-sectional study providing initial insights into waste generation, management practices, and other relevant factors, a longitudinal study can be implemented by repeatedly collecting data from the same population over time. Thus, the longitudinal study's cross-sectional data from different time points can be compared to identify changes and patterns, given the dynamic nature of urbanisation and demographic shifts in Abuja.

3. While composting might not generate electricity, its potential for waste reduction and soil enrichment merits exploration. Therefore, future research is necessary to evaluate the feasibility and impact of small and large-scale composting initiatives in Abuja.

4. As WtE is new ground for Nigeria, like most developing countries, decision support tools or frameworks that integrate various socio-economic, environmental, and technical parameters can aid in selecting suitable waste management strategies. Therefore, there is a need for future research to expand on the techno-economic assessments of WtE technologies in Nigeria, with a focus on site-specific conditions in Abuja, which would provide a more accurate estimation of energy recovery potential, economic viability, and environmental impacts. The researcher proposes the use of MCDA techniques for future research.

8.8. Final Note

In conclusion, this final chapter is a comprehensive culmination of the research process. It briefly summarises the critical outcomes derived from an in-depth analysis of the literature, a comprehensive survey questionnaire, and insightful semi-structured interviews. Incorporating these diverse sources of information has broadened the understanding and facilitated the generation of significant contributions to academic knowledge and practical applications in waste management and energy recovery. While this chapter highlights the research's accomplishments, it also acknowledges its limitations, which is vital for accurately interpreting the scope and implications of the study‘s findings.

Furthermore, this chapter contributes to developing a framework for action, offering a guide to navigating the key steps and considerations necessary for achieving the outlined objectives. This forward-looking perspective underscores the dynamic and ever-evolving nature of waste management and energy recovery, inviting continuous research to enrich our understanding further and drive sustainable advancements. In closing, the words of Nwachukwu *et al*. (2017) aptly capture the essence of this study and serve as a reminder of the enduring significance of our research endeavours.

"Solid waste research is driving solid waste management in developed nations, whereas solid waste management is driving solid waste research in developing countries."

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Appendices

Appendix A: Ethical Approval

Research, Innovation and Academic Engagement Ethical Approval Panel

Doctoral & Research Support
Research and Knowledge Exchange,
Room 827, Maxwell Building
University of Salford
Manchester
M5 4WT

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17 March 2020

Eta Ojiji

Dear Eta

RE: ETHICS APPLICATION STR1920-010: Towards Waste to Energy in the developing economies. An Analysis of the Prospects and Challenges of Waste Management Systems: A Case Study of Nigeria.

Based on the information you provided, I am pleased to inform you that your application STR1920-010 has been approved.

If there are any changes to the project and/ or its methodology, please inform the Panel as soon as possible by contacting S&T-ResearchEthics@salford.ac.uk

Yours sincerely,

Dr Anthony Higham
Chair of the Science & Technology Research Ethics Panel

Appendix B: Questionnaire Introduction and Consent Form

Research Title: Towards Energy Recovery from Waste in the Developing Countries. An Analysis of the Challenges, Barriers and Prospects of Waste Management in Abuja, Nigeria

---

Introduction and Privacy Notice

This survey is mainly for educational purposes as it is a partial fulfilment of the requirements for the degree of study.

Note: This survey is only open to residents of Maitama, Jabi, Gwarinpa, Durunmi and Gudu districts

This research is being carried out for the purpose of understanding the challenges with the Nigerian waste management system and what is being done to increase practice standards. The information obtained from this study is meant to contribute to improving waste management practices in Nigeria.

All information will be kept strictly confidential, and your name will not be used or published.

Taking part in this survey is voluntary and you are free to withdraw at any time, without giving a reason.

Please note that by completing this survey, you are giving consent for the information to be used in the thesis and any published works resulting from the research.

Consent

I consent to participate in this survey **(Tick the appropriate box)**

Yes	
No	

Appendix C: Survey Questionnaire

Section A: Socio-demographic and Housing Characteristics

A1. What is your gender? **(Tick the appropriate box)**

Male	
Female	
Prefer not to say	

A.2 Which of the following categories includes your age? **(Tick the appropriate box)**

18 – 24	
25 - 39	
40 - 59	
60 +	

A.3 What is your level of education? **(Tick the appropriate box)**

Primary	
Secondary	
Tertiary	
None	

A.4 What is your occupational status? **(Tick the appropriate box)**

Unemployed	
Self-employed	
Civil servant	
Private Sector employed	
Student	

A.5 What is your religion? **(Tick the appropriate box)**

Christian	
Muslim	
Traditionalist	
None	
Other	

A.6 Which district in Abuja do you reside in? **(Tick the appropriate box)**

Maitama	
Jabi	
Gwarinpa	
Durunmi	
Gudu	

A.7 What is your household size? **(Tick the appropriate box)**

1	
2 - 4	
5 - 7	
8 - 10	
More than 10	

A.8 What is your accommodation type? **(Tick the appropriate box)**

Detached house	
Block of flats	
Semi-detached house	
Shacks/Bacha	
Self-contained/One Bed	
Other	

Section B: Waste Generation and Composition

B. 9: How much waste do you generate daily? **(Tick the appropriate box)**

Over 6 kg	
4 – 6 kg	
2 – 4 kg	
Less than 2 kg	

B. 10: Please rank the following waste types in order of the waste you mostly generate, where 1 is most common, and 5 is least common. **(Do not select more than one answer per row)**

Waste Components	**1**	**2**	**3**	**4**	**5**
Food/Kitchen					
Paper					
Plastics					
Glass					
Metals & Tins					

Section C: Waste management practices and services

C.11: Using the scale below, please identify your level of knowledge of the under-listed waste management subjects **(Do not select more than one answer per row)**

	Very poor	**Poor**	**Average**	**Good**	**Excellent**
Recycling					
Reuse					
Waste reduction					
Waste separation					
Waste to Energy					

C. 12: Who do you think should be responsible for waste management in Abuja? **(Tick the appropriate box)**

Government	
Private Companies	
Abuja Environmental Protection Board (AEPB)	
Public	
All of the Above	

C. 13: Who is responsible for your waste collection? **(Do not select more than one answer)**

AEPB Contractor	
Informal Waste Pickers	
Self-disposal (burn/bury)	
Other	

C. 14: How often is your waste collected for disposal? **(Tick the appropriate box)**

More than twice a week	
Twice a week	
Once a week	
Less than once a week	

C. 15: What type of vehicle is used for your waste collection? **(Do not select more than one answer)**

No vehicle	
Pushcart/Wheelbarrow	
Open truck/Tipper	
Closed truck/Compactor	

C. 16: What time of the day is your waste most often collected? **(Do not select more than one answer)**

No idea	
At night	

During the day	

C. 17: Are you always willing to pay for waste collection services? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 18: Do people dump waste indiscriminately in your locality? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 19: Why do you think people dump waste indiscriminately? **(Do not select more than one answer)**

Lack of enforcement	
No provision of alternate disposal	
To avoid paying	
Delays in waste collection	
Lack of awareness	

C. 20: How often do you get information regarding waste management? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 21: How often do you participate in the environmental sanitation exercise? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 22: Do you agree that the environmental sanitation exercise has been effective? **(Do not select more than one answer)**

Strongly agree	
Agree	
Neither agree nor disagree	
Disagree	
Strongly disagree	

C. 23: Do you separate your waste at source? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 24 Do you recycle your waste? **(Do not select more than one answer)**

Always	
Often	
Sometimes	
Rarely	
Never	

C. 25: What is your level of satisfaction? with the following areas of waste management? **(Tick the appropriate box)**

	Very dissatisfied	Dissatisfied	Neutral	Satisfied	Very satisfied
Waste Infrastructure					
Waste Collection					
Government laws and policies					
Fees and levy					
Information and communication					

END OF QUESTIONNAIRE - THANK YOU FOR YOUR PARTICIPATION……………………………………………..

Appendix D: FGD Invitation and Consent Letter

LETTER OF INVITATION TO PARTICIPATE IN FOCUS GROUP DISCUSSION

To:

Date:

Dear <Name>

You are invited to participate in a focus group meeting titled **“Towards Waste to Energy in developing countries. An Analysis of the Challenge, Barriers and Prospects of Waste Management in Abuja Nigeria.”**

This study is mainly for educational purposes as it is a partial fulfilment of the requirements for the degree of study (PhD Environmental Studies) at the University of Salford, United Kingdom. The research focuses on stakeholder responsibilities, waste management frameworks and government policies, identifying the challenges and barriers in the study area and providing a range of targeted recommendations to develop proper waste management policies and strategies to facilitate waste-to-energy development plans.

To assist in this work, we are consulting with various stakeholders in the waste management sector, and you have been chosen to take part in this study as one of the stakeholders. Your view matters based on your experience and the challenges you might be facing with current waste management practices in Nigeria.

You will be participating alongside your colleagues and other experts drawn from other government agencies and private businesses.

We would therefore like to invite you to take part in the discussion at ……………………………………….. on

…………………………...

The discussion will start at …….., and finish around ……….

The discussion will be hosted by, a researcher from the University of Salford, with segments to be led by experts in the waste sector.

Your identity will remain anonymous, and you will NOT be personally identified in any subsequent reports. Also note that attendance and participation give consent for the information to be used for the research purposes.

We are sure that the group will result in lively discussion and will once more contribute to the enhancemet of the environment within Abuja.

If you have any queries regarding these discussions, then please contact the researcher for further information.

Thank you for your support, we look forward to seeing you.

Yours sincerely

Appendix E: FGD Agenda

Research Topic: Towards Energy Recovery from Waste in Developing Countries: An Analysis of the Prospects and Challenges of Waste Management in Abuja, Nigeria

Moderator: (Researcher)
Co-moderator: ……………………………………..

Part A: Welcome and Introduction

1. Housekeeping, welcome message and icebreaking activity led by moderator.
2. Purpose of study and general modes of discussions by moderator.
3. General introduction by everyone present.
4. Signing of attendance and explanation of "Consent" and recording of discussion.

Part B: FGD Questions and Prompts

5. What are the general barriers to sustainable waste management in the Abuja metropolis?
6. Why is open dumping common practice in the metropolis?
7. What are the issues surrounding waste collection within the various districts in the metropolis?
8. Can we discuss on the activities of the informal waste pickers?
9. Is the public willing to pay for waste services? If not, why?
10. How do the public get information on waste management? Is this effective?
11. Is the government doing enough to support waste services? In your opinion, what more needs to be done?
12. Are the current waste legislations and policies sufficient to guide sustainable waste management?
13. What do you know about energy recovery from waste?
14. Would anyone like to add anything else before we close?

Part C: Closure

15. Brief recap of discussion
16. Next phase of research
17. Thank you for coming!

Appendix F: Summary of Survey Demographic Characteristics

Demographic variable	Frequency	Percentage %
Gender		
Male	154	45
Female	175	51
Prefer not to say	8	4
Age Group		
18-24	92	27
25-39	155	45
40-59	90	27
60+	6	1
Level of Education		
Primary	44	13
Secondary	100	29
Tertiary	179	52
None	19	6
Occupation		
Unemployed	69	20
Self-employed	105	31
Civil servant	69	20
Private sector employed	46	14
Student	52	15
Religion		
Christian	213	62
Muslim	105	31
Traditionalist	14	4
None	7	2
Other	3	1
Maitama	29	8.5
Gwarimpa	137	39.9
Jabi	48	14
Durunmi	74	21.6
Gudu	55	16
1	24	7
2 - 4	120	35
5 - 7	151	44
8 - 10	41	12
More than 10	7	2
Detached House	48	14
Block of Flats	108	31
Semi-detached house	71	21
Shacks	22	6
Self-contained/One bedroom	81	24
Other	13	3.8