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QUANTIFICATION, CHARACTERIZATION, AND MANAGEMENT PRACTICES OF MUNICIPAL SOLID WASTE IN BUCHANAN, LIBERIA

AMA MARDEA AWOTWE

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QUANTIFICATION, CHARACTERIZATION AND MANAGEMENT PRACTICES OF MUNICIPAL SOLID WASTE IN BUCHANAN, LIBERIA

BY

AMA MARDEA AWOTWE

A thesis submitted to the Department of Environmental Science of the School of Biological Sciences, College of Agriculture and Natural Sciences, University of Cape Coast, in partial fulfilment of the requirement for the award of Master of Philosophy degree in Environmental Science

OCTOBER 2023

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DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my own original research and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature: ……. Date: ……

Name: Ama Mardea Awotwe

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of the thesis laid down by the University of Cape Coast.

Supervisor's Signature: ……. Date: ……

Name: Dr. Ernest Kofi Amankwa Afrifa

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ABSTRACT

Solid Waste Management (SWM) remains a challenge for many developing and transition countries. Buchanan City in Liberia is not an exception. While the volume of solid waste disposal at authorized and unauthorized places in Buchanan City continues to increase, our understanding of the quantification, characterization, and management practices remains limited. This study evaluated the generation rate and physical composition of domestic solid waste. It also looked at the management practices, institutional framework, and community's willingness to pay for improved waste management service in Buchanan City. The ASTM D521-92 standard was followed to quantify and characterize the municipal solid waste generated in Buchanan City. A descriptive cross-sectional survey was also employed to assess the institutional framework and management practices of municipal solid waste in Buchanan. The mean waste generated was in the order 2342.4 kg >1957.3 kg >1865.5 kg for the middle-income, high-income, and low-income areas respectively. The high-income area recorded the highest per capita waste generation rate (PCWGR) of 0.84 kg/capita/day whilst the lowest of 0.34 kg/capita/day was recorded in the low-income area. On average, the organic waste fraction recorded the highest of 19.7% across the three income levels. The study shows that awareness among residents regarding waste management strategies was low. Furthermore, most respondents expressed their willingness to contribute financially to improved waste collection services in Buchanan City. Residents also identified the inadequacy of waste bins as the greatest challenge to the current waste management system of Buchanan. There is a need for some form of institutional outreach or public education efforts to improve the residents' awareness of the city's waste management strategy. Also, adequate waste bins should be made available to enhance the efficient management of waste in the city.

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KEYWORDS

Buchanan City Corporation

Institutional Framework

Per Capita Generation Rate

Physical Composition

Solid Waste Management Practices

Willingness to Pay

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DEDICATION

This work is dedicated to my beloved daughter Shirley Wilma Brown and my family.

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ABBREVIATIONS

MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
BCC	Buchanan City Corporation
EPA	Environmental Protection Agency
WTP	Willingness to Pay
CDC	Cities, Districts and Counties
PCWGR	Per Capita Waste Generation Rate
SWM	Solid Waste Management
WMDs	Waste Management Departments
LDPE	Low-Density Polyethylene
HDPE	High-Density Polyethylene

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CHAPTER ONE

INTRODUCTION

Background to the study

Solid Waste Management (SWM) unquestionably stands as one of the most essential functions offered by municipal authorities worldwide. As populations grow and consumption rates rise, cities expand, with challenging SWM. This poses significant threats on both the environment and human health (Fadhullah et al., 2022). The scope and complexity of SWM have evolved drastically in recent years, presenting new challenges for city corporations especially in developing and transition countries. As urban centres become more populous and industrialized, the waste generated becomes more diverse, including everything from household waste to industrial by-products. This necessitates innovative and adaptive approaches to waste management, as well as an understanding that SWM has become a major budgetary concern for municipalities in developing countries. Therefore, striking the right balance between delivering high-quality waste management services and ensuring cost-effectiveness becomes a delicate balancing act for local governments (Fadhullah et al., 2022).

In urban communities, the sheer magnitude of waste generated daily is staggering; swift and efficient collection, transportation and disposal are vital to prevent the accumulation of waste in public spaces, which can lead to health hazards and environmental degradation. Furthermore, inadequate waste management practices can result in the proliferation of pests and diseases, leading to potential outbreaks and jeopardizing the overall well-being of residents (Das et al., 2019). Unfortunately, in many developing countries, the

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SWM infrastructure is still rudimentary and unable to cope with the mounting volumes of waste. This creates significant challenges for authorities, who must urgently address these issues to prevent further harm to both the environment and public health (Gwenzi, 2022).

Furthermore, to create and put into operation efficient SWM systems, it is essential to have precise information regarding the volume and categories of materials being produced as waste. Waste composition studies play a pivotal role in understanding the nature of the waste stream, identifying recyclable and recoverable materials, and determining appropriate processing methods (Gwenzi, 2022; Mulya et al., 2022; Das et al., 2019). These studies provide valuable insights into potential opportunities for materials recovery and the creation of circular economies that minimize waste and maximize resource efficiency.

Additionally, comprehensive, and reliable waste management data is crucial for a thorough and informative assessment of waste management options in various waste management programs in developing countries (Guerrero et al., 2013; Das et al., 2019). However, many developing countries, including Liberia, face a significant deficit in fundamental waste statistics (David et al., 2020). In cases where data exists, it often lacks consistency as it comes from multiple sources that are not validated and may be based on assumptions rather than scientific measurements (Gwenzi, 2022; Mulya et al., 2022). This situation can create confusion and uncertainty for potential investors in the waste management sector.

The absence of reliable data hampers the decision-making process for local and national waste management authorities. Furthermore, the most developing

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countries, like Liberia, do not have enough resources or personnel to perform research that includes gathering relevant data on the waste's composition and the amount of waste that is transported to treatment, recycling, or disposal facilities (David et al., 2020; Maiurova et al., 2022).

Buchanan, a city experiencing rapid growth in Liberia, has been wrestling with mounting issues in SWM. The city's status as the capital of Grand Bassa County and a port city has led to an increase in population and improved living standards, resulting in a significant rise in the amount and composition of solid waste generated. Consequently, the existing solid waste management system and institutional framework have been overwhelmed and unable to cope with the escalating waste volumes (Maiurova et al., 2022). Buchanan City lacks comprehensive data on solid waste management. The Buchanan City Corporation lacks a proper strategy to address the growing waste problem.

According to David et al. (2020), the city of Monrovia is currently facing a significant issue with the abundance of waste that is created as a result of human activities. This situation not only poses serious environmental and health hazards but also degrades the overall quality of life for residents in Liberia. Studies show that households in developing countries, including Liberia, generate the majority of municipal solid waste (55-80%), followed by commercial areas (10-30%), and smaller amounts from streets, industries, and institutions (Aung et al., 2019; Bui et al., 2020; Das et al., 2021). The waste generated from various sources contains a heterogeneous mix of materials, such as food waste, yard waste, wood, plastics, papers, glass, metals, rubber, inert materials, batteries, paint containers, textiles, construction, and

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demolition materials. This diversity poses challenges in classifying and utilizing waste as raw materials. Before any meaningful treatment process, solid waste must be quantified and characterized.

Additionally, it is crucial to emphasize that sorting and segregating solid waste at its source represent fundamental stages within a comprehensive waste management system. These approaches hold the promise of offering valuable insights into waste generation patterns and the characteristics of various waste components. Also, data on SWM practices and the local community's willingness to pay for waste collection services are significant (Bui et al., 2020). Efficient management of solid waste hinges on the active involvement of those generating waste, their adherence to sorting and separation guidelines, and their willingness to cover the costs of collection services.

This study aims to gather comprehensive household and administrative data to aid in the planning and implementation of effective waste management initiatives in Buchanan City, Liberia. Additionally, the study aimed to assess the available SWM system in Buchannan City and the local community's willingness to pay for waste collection services in three distinct socioeconomic areas. Specifically, the study assesses how well these households are willing to pay for waste management services and the current waste management practices at the Buchanan City Corporation (BCC).

Statement of the Problem

Improper Municipal Solid Waste Management (MSWM) remained a widespread issue environmental challenge in Liberia. The anticipated rise in solid waste generation due to population growth, shifting consumer habits, and

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economic expansion further exacerbates the situation (Shafy & Mansour, 2018). The waste management sector in Liberia already faces numerous obstacles, including overlapping and confusing legal mandates and obligations (UNEP, 2007). Effective waste management requires reliable national waste balance plans and increased knowledge of the issue on a global scale. Furthermore, the absence of reliable national waste balance plans, along with limited knowledge of primary waste flows, negatively impacts waste management on a global scale (Calvo et al., 2014).

The main challenge is the absence of up-to-date and comprehensive data on per capita solid waste generation rate, physical composition, and management practices. While some studies have explored waste disposal practices and population-linked with waste generation in Monrovia, Liberia (Casali et al., 2019; Vijay, 2020), no studies have provided adequate and comprehensive data specifically for Buchanan City, Liberia. The availability of relevant data on solid waste generation rate and the institutional framework is still limited. Also, existing waste management practices are poorly documented, and the willingness to pay for improved waste services remains unknown. Addressing these limitations are essential for the successful implementation of community-based initiatives to effectively tackle waste management. This study therefore seeks to bridge these knowledge gaps and improve waste management strategies, with comprehensive waste management approaches and up-to-date data on waste generation and physical composition in Buchanan City, Liberia.

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Main Objective

The main objective of this study was to quantify, characterise and assess the management practices and per capita generation rate (per capita) of domestic solid waste at three socio economic levels in Buchanan city, Liberia.

Specific Objectives

The specific objectives of the study were to:

i. Estimate the physical composition and quantity of domestic solid wastes generated at three socioeconomic levels in Buchanan city, Liberia
ii. Evaluate the solid wastes management practices among selected residents in Buchanan, Liberia
iii. Assess the existing institutional framework for municipal solid waste management in Buchanan city, Liberia
iv. Assess residents' willingness to pay for improved solid waste management services in Buchanan city, Liberia

Research Questions

i. What is the physical composition and quantity of domestic solid waste generated at the three socioeconomic (high, medium and low income) levels in Buchanan City, Liberia?
ii. What are the waste management practices within the selected households in Buchanan?
iii. What are the institutional frameworks for effective solid waste management in Buchana City, Liberia?
iv. Are the residents willing to pay for improved solid waste management services in Buchanan City, Liberia?

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Significance of the study

This study complements the existing body of knowledge on solid waste quantification and physical composition in Liberia. The goal is to create efficient strategies for managing solid waste in Buchanan City. Additionally, it aims to provide crucial information to policymakers, municipal authorities, and stakeholders, enabling them to make informed decisions on implementing sustainable waste management practices in Buchanan City and Liberia. Again, the assessment of residents' willingness to pay for improved waste collection services in this study will shed light on community engagement and public participation in waste management efforts. Understanding the community's perspectives and preferences will help design waste management programs that align with the needs and expectations of residents, increasing the likelihood of successful implementation. Additionally, the findings from this study will provide valuable insights to encourage investments that can drive improvements in waste management infrastructure and technology in Liberia.

Besides, this study's contribution to sustainable solid waste management practices is closely linked to achieving several Sustainable Development Goals (SDGs), including SDG 11 (Sustainable Cities and Communities), SDG 12 (Responsible Consumption and Production), and SDG 13 (Climate Action), and can be leveraged upon to drive positive changes in waste management strategies and foster a cleaner, healthier, and more sustainable environment for the residents of Buchanan and Libera.

Delimitation of the study

The main goal of this research is to measure and characterize solid waste from municipalities and the methods used to manage it in Buchanan

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City, Liberia. However, to determine the generation (the sum of waste) and management (collection, transportation, disposal) strategies employed by households in the study region, this research concentrated on the generator-based source at the household level. The research did not include waste produced at the commercial and industrial levels. Furthermore, the researcher lacks the resources and time to cover all the areas because Buchanan is an extensive area separated into communities. In consideration of this, the investigation was carried out in selected communities in Buchanan.

Limitations of the study

The study was exclusively carried out during the wet season, spanning a duration of four months. Additionally, the research encompassed three income categories, namely High, Middle, and Low. The research only considered waste generated at the household level without waste generated from commercial and other institutions. Notwithstanding, the results obtained reveal an indication of the municipal solid generation rates and composition generated by some residential areas in Buchanan.

Organization of the study

The study is organized into six sections. The initial chapter serves as an overall introduction to the study, encompassing the background, problem statement, research objectives, research questions, and significance of the research. The second chapter provides an examination of pertinent literature, and the third chapter outlines materials and methods used in the research. The findings (results) are analysed and presented in Chapter four whilst Chapter five discusses the results. Finally, Chapter six contains the recommendations and conclusions drawn from the study.

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CHAPTER TWO

LITERATURE REVIEW

Introduction

Population growth, economic expansion, and improved living standards have led to an increase in MSW generation, posing a global challenge (Abdel-Shafy et al., 2018). This challenge is particularly pronounced in urban and semi-urban centres of developing nations such as Liberia, where improper MSW management is a widespread environmental and social problem (David et al., 2020). Srivastava et al. (2015) demonstrated a remarkable contrast in the pace of change in both the per capita waste generation rate (PCWGR) and the physical composition of municipal solid waste between developed and developing countries.

Generally, a higher level of economic prosperity and a larger proportion of the population residing in urban areas correlate with a greater volume of solid waste produced. However, there is significant evidence of a breakdown SWM in urban areas of Liberia. A study by Nnaji (2015) shows how it has become a national concern in Nigerian urban areas and cities that solid waste generation, management, and disposal are issues. Hence, this situation mirrors that of Liberia, where waste management has emerged as a recent and undeniable challenge. In recent times, there has been a significant increase in the daily production of waste in Liberia. Approximately 85% of the population discards their waste either in authorized or unauthorized locations within their localities (David et al., 2020).

The limited capacity to effectively manage solid waste leads to unsanitary circumstances, as highlighted by Nanda and Berruti (2021). To a

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large extent, solid waste is a natural part of human activities, involving the accumulation, utilization, and elimination of materials. The quantity of waste produced by modern society is closely linked with the standard of living, socio-economic factors, and cultural characteristics of the specific environment (Hens et al., 2018).

Hence, there arises a necessity to embrace an efficient strategy for managing waste, aiming to mitigate the issues and challenges in waste handling. Information related to MSW shows considerable variability across various waste studies. Most waste management decisions only consider household waste, but industries and businesses often hide information to avoid legal responsibilities (Chandrappa & Das, 2012). The valuable materials present within the solid waste stream can be reclaimed and repurposed, thereby minimizing the volume of waste ultimately deposited in landfills. However, owing to the heterogeneous nature of waste, making projections for recycling and reuse, as indicated by Nanda and Berruti (2021), becomes an immensely challenging task.

Additionally, Gausman et al. (2019) emphasise that indiscriminate solid waste disposal is prevalent in developing countries and this viewpoint holds relevance for this research as it relates to the situation where waste produced in Liberia is combined without onsite sorting and indiscriminately disposed.

Another study by Knickmeyer (2020) highlighted the importance of understanding the composition of solid waste, which influences waste density, proposed disposal methods, and considerations for waste reduction, reuse, and recycling. Also, Das et al. (2019), further emphasized the necessity of a

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comprehensive characterization of MSW, imposing its important role in facilitating efficient and cost-effective long-term planning for SWM.

The identification of waste composition plays a crucial role in determining the most suitable technology for treatment. This involves considering important health precautions and the space requirements for treatment facilities, as highlighted by Abdel-Shafy and Mansour (2018). Despite the importance of this factor, there has been a clear absence of research focused on analyzing the quantity and physical composition of municipal solid waste in Buchanan City, Grand Bassa, Liberia (David et al., 2020).

This oversight is significant, especially given the extensive efforts in waste management, primarily within major urban cities like Monrovia, Ganta, Gbarnga and Buchanan. The objective of this study is to close this disparity by providing precise information regarding the PCWGR and physical composition of household solid waste. Also, the SWM practices and existing institutional frameworks in these distinct residential areas of Buchanan city, Liberia. The objective is to enhance the comprehensive waste types being generated, thereby contributing to effective waste management strategies.

Municipal Solid Waste

Waste is more readily identifiable than precisely definable. It comes into the category of waste when it is no longer of use to its owner, or when it is employed but falls short of fulfilling its intended purpose (Graham-Rowe et al., 2014). Kamaruddin et al. (2017) defines municipal solid waste as encompassing both household waste and commercial waste, which share similarities in terms of their inherent nature and physical composition.

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Municipal solid waste originates from three primary sources: households, commercial enterprises, and other origins (Keske et al.,2018).

According to MogboTochukwu et al. (2019), MSW encompasses a range of items, including both durable and nondurable goods, packaging materials, food scraps, yard clippings, and assorted types of inorganic waste. This data holds significant value for the research as it aids in the proper classification of waste materials. Municipal waste, as clearly explained in a study by Ahsan et al. (2014), comprises discarded items from residences, markets, vendors, stores, and various business operations within a specified area.

Sources and Types of Municipal Solid Waste

To design and manage effective systems for municipal solid waste, it is crucial to have a comprehensive understanding of the origins and categories of solid waste in each area (Priti & Mandal, 2019). This understanding forms the foundation for evaluating the physical composition and per capita generation rate for MSW within a community, especially pertaining to residential units. The classification of solid waste types is detailed in Table 1. Another categorization introduced by Bala et al. (2022) classifies solid waste based on characteristics like biodegradability, non-biodegradability, and the level of risk posed (hazardous waste). Moreover, sources of solid waste include households, retail outlets, commercial establishments, hotels/restaurants/food stalls, slaughterhouses, and various other contributors.

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Table 1: Origin and Categories of Solid Waste

Origin	Typical waste generation facilities, activities, or locations	Solid waste categories
Household	Low-medium-and-high-rise houses, single-family and multifamily attached houses, etc.	Food waste, paper, plastics, textiles, rubber, yard waste, wood, glass, tin cans, aluminium, other metals, ashes, street leaves, special wastes, and household hazardous waste.
Commercial	Stores, restaurants, Clubs markets, offices, buildings, motels, print shops service, stations, shops, etc.	Paper, plastics, wood, food, waste, glass, metals, special wastes, etc
Institution	Schools, hospitals, institutions, banks, governmental & non-governmental intuition, etc.	As shown above in Commercial
Municipal Services	cleaning of the streets, landscaping, cleaning of catch basins, parks and beaches, and other recreational areas	Special wastes, sweepings from the streets, tree, and landscaping trimmings, waste from catch basins, and general waste from parks, beaches, and recreation areas.

Source: Adapted from Puopiel (2010)

Characteristics of Municipal Solid Waste

The nature and volume of solid waste produced in an area are influenced not just by the residents' quality of life and way of living, but also by the availability and kind of natural resources in that area (Burns et al., 2021). In order to reduce the amount of waste reaching the final disposal site and implement an efficient, environmentally friendly solid waste management (SWM) strategy, it is crucial to first determine the characteristics and composition of urban waste within the city (Das et al., 2019).

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Municipal Solid Waste Management

In less developed nations, the proper handling of solid waste is met with several challenges, which encompass limited coverage and irregularity in waste collection services (Puopiel, 2010). Furthermore, the presence of insufficient waste disposal sites, marked by expansive open dumps, along with unregulated burning practices leading to air and water pollution, creates an environment conducive to the proliferation of pests such as flies and rodents (Williams et al., 2019). Moreover, the management of informal waste collection activities further complicates the situation. This issue holds significant relevance in Liberia, particularly in Buchanan, where waste management services demonstrate notable inefficiency and ineffectiveness. Between one-third to one-half of solid waste in low- and middle-income countries, including Liberia, remains uncollected (Karak et al., 2012)

The effective and cost-efficient planning of long-term solid waste management relies on understanding how solid waste is produced and structured (Mmereki et al., 2016). This involves making choices about the equipment used for waste treatment and handling, as well as determining suitable disposal facilities that can enable the recovery of energy and resources. This information is particularly important for research since there is currently no available data regarding the generation of solid waste in Buchanan.

Comprehending the composition of MSW is indispensable for proficient waste management for several compelling reasons. These encompass the need to anticipate potential material recovery, pinpoint sources of constituent generation, facilitate the development of processing equipment,

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measure the physical, chemical, and thermal attributes of the waste, and ensure compliance with regulatory measures (Kamaruddin et al., 2017). Waste management plays a crucial role in environmental conservation. A comprehensive understanding of municipal solid waste (MSW) serves as a fundamental building block for efforts to enhance municipal solid waste management services (Diaz et al., 2020). The development of municipal waste management (MWM) systems and efforts to improve them both depend on accurate projections of solid waste generation (Almasi et al., 2019).

To achieve an effective and well-organized approach to managing solid waste, it is important to clearly identify and comprehend the fundamental elements involved (Oduro-Appiah et al., 2021). According to Karak et al. (2012), municipal solid waste management (MSWM) encompasses a range of activities dealing with waste at various stages, both prior to and after its generation. These activities include waste minimization, transfer, storage, segregation, recovery, recycling, and ultimate disposal. In the context of urban areas, MSWM refers to the comprehensive management of solid waste, involving processes such as collection, transportation, treatment, resource recovery, recycling, and responsible disposal, as highlighted by (Hemidat et al., 2022). The framework of MSWM integrates key practices like source separation, waste reduction, collection, transportation, treatment, recovery, recycling, and final safe disposal, all executed with a strong commitment to environmental sustainability.

MSWM Hierarchy

The Waste Management Hierarchy (WMH) stands as a widely accepted principle within national and regional policies, often forming the

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very bedrock of contemporary MSWM practices. This hierarchy arranges waste management actions based on their ecological and energy-related characteristics (Fetanat et al., 2019). In the African context, it has been noticed that the most viable method for handling waste in many urban cities, such as Buchanan and Monrovia involve adhering to the municipal solid waste hierarchy. Additionally, it calls for reduced technological complexity while maintaining a sustainable approach. The hierarchy functions as a potent policy instrument for conserving resources, addressing landfill capacity constraints, ensuring a clean environment, and safeguarding public health (Parvin et al., 2020).

The waste hierarchy, also known as the waste management hierarchy or waste minimization hierarchy, is a concept and framework that outlines a preferred order of actions for managing and dealing with waste in an environmentally responsible manner. The goal of the waste hierarchy is to minimize the environmental and societal impacts of waste generation and disposal while promoting resource efficiency and sustainability. The waste hierarchy typically consists of five levels, (Prevention, reuse, recycling, recovery, and disposal)

Prevention

The highest and most preferred level of the waste hierarchy is waste prevention, also known as source reduction or waste minimization. This involves taking steps to reduce the generation of waste in the first place. Strategies for waste prevention include designing products with longer lifespans, reducing packaging, improving product durability, and encouraging consumer behavior changes to reduce waste. Notably, a substantial reduction

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in waste volume can be achieved through source reduction, an idea underscored by Degli Antoni and Marzetti (2019) who advocates for increased backyard composting. The adoption of composting practices outlined in this proposal holds substantial implications for the research, as it can redirect a substantial portion of waste away from the ultimate disposal site (Almazán-Casali., 2019).

A study by Okot-Okumu (2012) uncovered a lack of formal material recovery systems in Africa, but noted a prevalent trend of repurposing plastics, bottles, paper, and cans for domestic use, particularly among urban underprivileged individuals.

Reuse

The second level in the hierarchy emphasises the principal of reuse. Reusing waste products or waste materials means using them again for their original purpose or finding alternative uses to extend their lifespan. This can include activities such as repairing, refurbishing, or repurposing items. Reuse helps conserve resources and reduces the need for new production (Ayodele et al., 2018).

Recycling

Recycling of MSW is the process of collecting, sorting, processing, and converting waste materials into new products, materials, or energy. Recycling helps recover valuable resources, conserves energy, and reduces the environmental impacts associated with extracting and manufacturing virgin materials. Examples of commonly recycled materials include paper, glass, plastic, and metals (Ayodele et al., 2018).

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Recovery

According to Knickmeyer (2020), refers to any process where the primary objective is to make waste serve a useful purpose by replacing other resources that would have been used to perform a certain function. Waste materials can be recycled, composted, or converted to energy (Nkwachukwu et al., 2010). Furthermore, recycling plays an important role in diverting a significant portion of waste from disposal sites, making it an indispensable facet of a holistic solid waste management strategy. While the reuse and reclamation of non-metallic elements within the waste stream are noteworthy in waste management, a particular emphasis is placed on organic (biodegradable) residues. These residues typically constitute a substantial proportion of around 50% by weight of solid waste in many developing countries.

Also, many experts and researchers advocate composting as a promising avenue for effective recovery (Hoang et al., 2022). In terms of recovering resources from biodegradable components, a three-pronged approach is employed: firstly, these components can be used to enhance agricultural soil quality through composting (Manyi-Loh et al., 2019).

Disposal

The last stage of the waste hierarchy is disposal. This is the least preferred option and involves sending waste to landfills or other forms of waste disposal, such as deep burial. Disposal should only be considered when all other options have been exhausted, as it can have significant environmental and financial costs, including the potential for pollution and long-term environmental harm (Ayodele et al., 2018).

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Quantity and Physical Composition of MSW

The physical composition of municipal solid waste fluctuates depending on variables such as consumer behavior, economic growth rates, living standards, seasonal variations, days of the week, population habits, and geographical location (Best & Kneip, 2011). As a result, effective waste management is crucial, but rapid urbanization and changing waste composition pose challenges. This complexity makes it difficult to apply successful waste management approaches from other locations, as waste characterization data cannot be easily extrapolated for decision-making in different areas. Thus, it becomes important to assess and characterize the municipal solid waste (MSW) of the specific area under investigation, which constitutes the central focus of the present study.

A profound significance lies in embracing the insights provided by surveys Regarding the amount of waste, as they play a critical role in shaping the foundational aspects of managing solid waste. These aspects encompass a range of factors, including the methodology and team size, storage techniques, disposal methods, collection type, and frequency, as well as the extent of resource recovery. These determinations not only facilitate the assessment of the prevailing conditions but also aid in predicting forthcoming waste trends. A lack of consistent data on waste composition and volume is a major factor in ineffective waste management. To establish an effective waste management scheme, it is imperative to gather quantitative insights into the composition of the waste being generated (Thyberg & Tonjes, 2016). For any community, it is indispensable to understand both the magnitude and rate of solid waste generation. This understanding allows for the efficient allocation of resources

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for budgeting, the operation of disposal facilities, and the formulation of strategies for processing. The insights into the characteristics of waste can serve as a blueprint for designing processing machinery and waste disposal sites. Particularly in the context of composting, a crucial focus rests on comprehending the biodegradable fraction of solid waste (Policastro & Cesaro, 2022).

Per Capita Municipal Solid Waste Generation

Several approaches are at one's disposal to determine the quantity of waste necessitating disposal (Shekdar, 2009). The validity of the findings hinges on the methodology chosen, which encompasses tasks like evaluating the weight of each vehicle and its waste load upon arrival at the disposal site. This necessitates the availability of a sufficiently sizable weighing scale capable of accommodating vehicles of varying sizes. Alternatively, a different option involves the random weighing of a small subset of incoming vehicles. The third and least precise technique involves compiling the following data: one) average waste density, two) daily load count, and three) mean volume per load.

Among them, the specific weight method offers the most reliable insights into the potential amounts of projected waste. The quality of waste and the rates at which waste is generated per person are pivotal considerations in the development of an effective solid waste management program. The expenses related to collecting, treating, and disposing of waste are increasing annually, often constituting a significant portion of the local budget. Therefore, understanding these factors aids in enhancing operational processes. These cost increases stem from notable and concerning shifts in the nature and

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composition of waste materials (Hoornweg et al., 2013). Generally, more developed nations tend to generate a greater amount of solid waste per capita (ranging from 0.8 to 1.9 kg per day) in contrast to middle-income countries (with a range of 0.5 to 0.8 kg per day) and low-income countries (0.3 – 0.6 kg/d) (Ullah et al., 2022).

In every society, individuals generate domestic refuse, and the process of urbanization and industrial advancement has notably expanded the spectrum and volume of waste that necessitates collection and proper disposal (Cheng & Hu, 2010). To successfully establish a waste management facility, the waste manager needs thorough data regarding the quantities and categories of waste present both within and in the vicinity of the municipality. This information can then be incorporated into the waste management blueprint. Furthermore, it is imperative to forecast potential escalations in the amounts of each waste category, thereby facilitating proactive planning for the future provisioning of requisite facilities (Hoornweg et al., 2013).

Rapid urban population growth contributes to the escalation of solid waste quantities in numerous urban areas, while an improved standard of living leads to a heightened rate of solid waste creation and alterations in waste attributes (Usmani et al., 2020).

The characteristics of solid waste, such as biodegradable compounds, moisture levels, particle dimensions, composition, density, and compressibility, exert significant influence over the rate of degradation in landfill sites. For achieving a high level of precision in sampling, it is essential to conduct sampling directly at the source of waste generation. This involves implementing a practical program where specific sampling zones are carefully

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chosen and delineated. During the selection process, great care is taken to ensure that various socioeconomic groups are adequately represented. To accomplish this, Buchanan was divided into three socio-economic groups – high income, middle income, and low income aiming to encompass a comprehensive cross-section of the entire population.

In each selected sampling area, every participating household was equipped with a plastic bag, to collect their daily waste output. This method allows for the determination of both per capita waste generation and the overall quantity of waste generated. The sampling procedure is designed to provide a level of accuracy that is suitable for a wide range of purposes, including the design of facilities and equipment, as well as solid waste management plan.

Accurate predictions of solid waste generation are crucial for planning and designing municipal waste management systems. Certainly, I can rephrase it for you (Thanh et al., 2011)

However, the absence of complete historical data regarding the quantity and quality of solid waste, primarily attributable to budget constraints and a shortage of management capacity, has created a situation where formulating long-term system plans and short-term expansion initiatives becomes a challenging endeavour (Powell et al., 2018). Globally, the daily per capita quantities of solid waste produced exhibit significant variations. It can be argued that the economic status of an area plays a pivotal role in determining the volume of solid waste generated by a city (Das et al., 2019). Typically, estimates for the amounts of Municipal Solid Waste (MSW) are derived from the weight of waste generated per individual per day, measured

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in kilograms per person. Furthermore, the ability to forecast the quantity of solid waste produced holds paramount importance in the realm of municipal environmental management.

This predictive data serves multiple purposes. It not only aids in establishing environmental standards and evaluating the environmental consequences of waste but also plays a crucial role in gauging the potential amounts of solid waste that will be created and collected. This aspect carries significant significance in the selection of appropriate equipment, design of waste collection guidelines, establishment of materials recovery facilities, and creation of disposal facilities. Moreover, this data finds utility in budgetary planning and operational optimization. Additionally, it provides an essential foundation for programs focused on environmental economics and has the potential to greatly influence the ultimate targets and strategies of environmental management.

Physical Composition of MSW

Solid waste physical composition analyses play a significant role in studying the waste generated in a specific locality and in comparing various waste collection systems. For evaluations and comparisons to hold weight and credibility, they must be grounded in evidence-based knowledge about the system being studied. Additionally, it is to ensure that the samples selected for waste composition analyses accurately reflect the entire population. (Ugwu et al., 2020).

Well having a comprehensive understanding of the waste composition is crucial for several key aspects:

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- Deciding on the most suitable storage and transportation methods for a specific scenario,
- Assessing the potential for recovering valuable resources,
- Selecting an appropriate disposal approach, and
- Evaluating the potential environmental impact in case of improper management of the waste.

Besides, the variability in the physical composition of MSW has become increasingly significant, influencing subsequent processing and final treatment methods. The composition plays a pivotal role in determining the appropriate system for various waste management procedures. Pre-treatment plays a vital role (through segregation into different components, enabling the identification and segregation of recyclable materials) in the recovery of valuable potential products for reutilization in the market (Rahman et al., 2021).

Hence, in order to make the most of the waste stream and reduce the chances of residues being deposited in landfills, it's crucial to gain a comprehensive understanding of the waste by efficiently and effectively separating it at its origin. One of the most accurate techniques for determining waste composition entails collecting it at its source and categorizing it directly into distinct material categories (Edjabou et al., 2015). In another study by Karak et al. (2012), solid waste components remain largely consistent across the globe; however, their proportions vary significantly between countries and even within cities due to differences in economic status. To add on, developing nations tend to produce a substantial amount of waste containing organic matter, often three times more than industrialized nations. The variation in

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these figures can be attributed to factors such as income levels. In developing countries, waste tends to be denser and more moist, primarily because of the consumption of fresh, unpackaged foods like fruits and vegetables.

On the other hand, residents of developed nations consume more processed and packaged foods, resulting in their waste containing a higher proportion of packaging materials compared to that of developing countries. These physical characteristics play a pivotal role in shaping the viability of specific treatment approaches. Machinery and systems designed to handle low-density waste, as commonly seen in industrialized nations, would prove unsuitable and unreliable under such conditions. Moreover, beyond the increased weight, the abrasive nature of inert materials like sand and stones, alongside the corrosive impact of heightened water content, of equipment (Kumar & Samadder, 2017).

Municipal Solid Waste Characterization, Quantification, and Generation

The characteristics of waste play a crucial role in the planning of waste disposal facilities and the formulation of waste management policies, as noted by (Badgie et al., 2012). However, the current waste management system in Buchanan City lacks essential data about the amount and nature of waste produced. These factors contribute to inadequate solid waste management. To establish an effective and sustainable waste management program, it is important to gather quantitative information about the composition of waste generated in the area. To address this, it is crucial to directly source and characterize waste from households, as this specific and detailed data is vital for the investigation's objectives.

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Municipal Solid Waste Characterization

In developed countries, a variety of methods are utilized to handle waste, leading to the generation of renewable energy sources and the creation of new products such as compost (Shah et al., 2022). These countries invest significantly in waste recycling for agricultural benefits. Conversely, municipal solid waste management remains a notable weakness in developing countries, impeding their progress. Inadequate research on waste composition in planning waste management strategies in African urban areas hampers informed decision-making for incorporating waste management as an environmental safeguard. Waste characterization is recognized as a key element impacting effective recycling initiatives in developing nations (Guerrero et al., 2013).

Solid Waste Characterization Study

Sampling

This approach of sampling municipal solid waste depends on the specific objective of waste analysis. Obtaining a sample that faithfully reflects the entire waste population or the subject of examination is of utmost importance. Various essential factors must be established during waste sampling: The specific area or entity to be sampled, including important parameters like the number of households, dates for conducting the sampling, time duration for sampling (e.g collected waste during the day and week, etc.), sampling options: directly from a waste generator, from the collection or transport vehicle, and at the treatment facility, determining the appropriate sample size, and various sampling techniques can be employed to analyze the generation and composition of Municipal Solid Waste (MSW). These methods include

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options such as door-to-door waste collection or direct extraction from waste collection trucks (Kuluse & Gure, 2022). In this study, a stratified random sampling approach was utilized, dividing the study area into three distinct strata representing different living standards: high, middle, and low-income standards (Steuer et al., 2017).

Number of Households Sample Size Determination

According to the literature, the determination of the appropriate number of samples for solid waste characterization lacks a singular prescribed method. According to the municipal solid waste characterization methodology proposed by Vasileiou et al. (2018), sufficient data was collected from thirty samples. The sample count from each specific site accurately represents the corresponding populations within these areas. In adherence to the stratified standard of living classification, Nell (2020) determine that thirty households were randomly selected for each category, culminating in a total of 90 households chosen for collection and subsequent weighing.

The number representing households in the population can be determined using the following formula:

1. Cochran formula

This formula indicated below is used for an infinite population sample size (50,000 people and above)

$$\square = \frac{\square^2 \square * \square}{e^2} \quad \textbf{(1)}$$

Where as,

P = True proportion of factor in the population, or the expected frequency value

e = Maximum difference between the sample mean and the population mean,

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or Probable Frequency Value minus (-) Worst Acceptable Value

Z = Area under normal curve conforming to the desired confidence level

n= number of samples of infinite population

2. ***Sloven's formula in statistics***

For correction of the infinite population

$$n = \frac{N}{1+Ne^2} \quad (2)$$

Where,

n = sample size

N = population size

e = acceptable margin of error

The two formulas mentioned above resulted in a sample size of 100-150 households for a population ranging from 50,000 to 10 million persons. However, for waste characterization analysis, Nordtest (1995) recommends that 100-200 households are needed for a weekly analysis in a defined community. When variations exist due to factors such as housing types, municipality types, social and economic groups, among others, a representative sample should typically consist of 30-100 households per study area (Nordtest, 1995). Sloven's statistical formula was utilized to determine the number of households selected for this research. Municipal Solid Waste Quantification by Weight is considered the simplest and most effective method for quantification in many waste management programs (Nell, 2020). To assess the existing waste management practices, both weight quantification and category classifications have been chosen. Quantification by weight also facilitates the assessment of final design accuracy since records of waste disposal in landfills are typically documented by weight. This research

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quantifies household waste based on its weight, aligning with the perspective presented by Principato et al. (2019).

Willingness to separate waste and Source sorting

Source sorting of solid waste entails the separation of biodegradable materials from the overall waste stream before they are gathered along with other municipal solid waste (MSW). This approach allows for potential reuse, recycling, and composting, a practice commonly followed in developed nations but not prevalent in most developing countries like Liberia. In places such as Liberia, including Buchanan City, separating MSW into different categories is a crucial step toward establishing a sustainable and comprehensive waste management system. Certainly, sorting recyclable materials directly where they originate proves to be a more efficient method than attempting mixed waste recovery (Gyimah et al., 2021). This approach yields cleaner and higher-grade materials as a result. By separating materials at their source, recycling and composting facilities can access the necessary raw materials more readily, ultimately reducing the volume of waste that ends up in landfills. This separation, especially of organic waste, presents an opportunity to significantly decrease landfill-bound waste in developing countries by over 50% in terms of weight. As a result, source separation not only enhances the value of Municipal Solid Waste (MSW) but also extends the lifespan of landfills. The integration of waste separation into a comprehensive solid waste management approach necessitates a thorough understanding of the level and types of separation, as well as the willingness and capacity of the population to actively engage in the separation process. This knowledge can facilitate the creation of alternative waste management strategies aimed at

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diversifying the materials destined for landfill disposal. According to research conducted by Gyimah et al. (2021), approximately 75.3% of households expressed a willingness to segregate their waste if provided with complimentary bins. Likewise, 72.3% indicated they would participate if waste collection fees were lowered, while only 21.9% were open to separation without any incentives. As noted by Thi et al. (2015) more than 70% of households were prepared to separate waste, depending largely upon factors such as the availability of free bins.

Problems of Managing Municipal Solid Waste in Developing Countries

Several obstacles confront the management of solid waste in developing nations, including Liberia. These hurdles encompass issues like the collection and proper disposal of waste, limited coverage in waste collection services, irregularities in collection schedules, insufficient financial resources to sustain waste management efforts, lack of appropriate equipment for waste storage, and the practice of unregulated open dumping and burning, leading to air and water pollution concerns (Sibanda et al., 2017).

The uncritical transfer of machinery from developed nations to developing ones, known as "blind technology transfer," causes the challenges associated with managing municipal solid waste (MSW), as highlighted by (Tom, 2018). The subsequent failures of such transfers underscore the importance of adopting appropriate technologies tailored to the unique conditions of developing countries. These conditions encompass factors like the nature of solid waste, its physical composition, and the volume of waste generated.

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Consequently, the lack of comprehensive data regarding waste type, composition, and quantity presents a significant obstacle when it comes to selecting suitable treatment technologies. The accurate identification of waste composition emerges as a crucial factor in determining the optimal treatment technology. This process ensures the incorporation of essential health precautions and the efficient allocation of space for treatment facilities, as emphasized by Shekdar (2009). Understanding the nature of waste is essential before creating plans for its control and/or keeping information current. Scarce data results from the significant expenses associated with techniques originating in more advanced nations, as well as their unsuitable application in less developed nations. Both these factors hinder the establishment of efficient and enduring waste management systems in developing countries (Ghisellini et al., 2016).

Liberia's primary challenge in municipal solid waste management revolves around the scarcity of appropriate locations for solid waste disposal, as noted by Wilson et al., (2015). It is important to note that enhancing solid waste management entails decreasing the volume of waste directed to final disposal sites. This reduction becomes crucial considering population growth and the movement of people from rural to urban areas. A study by Mihai et al. (2021) noted that a common solid waste management system in a developing nation presents various issues such as limited waste collection coverage, inconsistent collection services, unregulated open dumping, and uncontrolled burning that lacks measures to prevent air and water pollution.

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Willingness to pay for improved solid waste management services

SWM is a critical issue in developing countries, where rapidly growing populations and urbanization have led to increased waste generation and limited resources for proper disposal. The willingness to pay (WTP) of the community for solid waste management services is an essential aspect to consider in addressing this challenge, as it directly influences the sustainability and effectiveness of waste management initiatives. Several studies have explored the factors that influence community WTP and its implications for solid waste management services in developing countries (Alhassan & Mohammed, 2013; Suryawan & Lee, 2023).

According to a study by Akter and Hossain (2017), community WTP for solid waste management services in Dhaka, Bangladesh, was influenced by factors such as income, education, household size, and awareness about waste management practices. The study highlighted that households with higher income and education levels were more willing to pay for improved waste management services, suggesting a positive correlation between socioeconomic status and WTP.

In a similar context, De Silva and Wijesekera (2019) conducted a study in Sri Lanka and found that community awareness about the environmental and health impacts of improper waste disposal significantly influenced WTP. Communities that were more informed about the consequences of poor waste management were more likely to be willing to contribute financially to improved waste collection and disposal services.

Another important factor that affects community WTP is the perceived quality of services. A study by Alemagi and Akam (2018) in Cameroon

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demonstrated that the quality of waste management services, including regular collection and disposal, influenced WTP. Communities that received more reliable and efficient waste management services were more willing to pay for the continued provision of such services.

Moreover, community engagement and participation in waste management decision-making processes have been shown to enhance WTP. In their research in Nigeria, Adelekan and Aladenola (2018) emphasized the importance of involving local communities in planning and implementing waste management strategies. When communities are engaged and have a sense of ownership in the process, their willingness to contribute financially to sustainable waste management practices increases.

However, it is important to note that there can be limitations to WTP studies in developing countries. Cultural and social factors, as well as affordability issues, may affect the accuracy of responses. A study by Van Houtven et al. (2015) in Kenya highlighted that respondents' stated WTP might not always align with their actual financial capacity to pay for waste management services. In conclusion, community willingness to pay for solid waste management services in developing countries is influenced by a combination of socio-economic factors, awareness, perceived service quality, and community engagement. To design effective and sustainable waste management programs, policymakers and practitioners should consider these factors and tailor strategies to local contexts, ensuring that services are affordable, accessible, and aligned with the community's preferences and needs.

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MSWM in Liberia

According to the Local Government Act of Liberia, the city cooperation of the Local and Rural government is tasked with overseeing solid waste management in Liberia. They supervise the decentralized Counties, Districts, and Cities (CDCs), which are mandated to handle waste management by the Local Government Act (2018). This legislation was established to require CDCs to initiate programs for creating essential infrastructure, offer municipal services, and promote responsible urban management and environmental conservation. within their districts. The CDCs are also responsible for gathering and properly disposing of solid waste through their waste management departments (WMDs) as well as the departments responsible for Environmental Health and sanitation. This implies that Municipal, CDCs, such as the Buchanan city corporation (BCC) must seek out the most efficient and viable system for collecting and disposing of solid waste, while also ensuring its sustainability. The CDC in Liberia is facing a substantial challenge in effectively managing solid waste disposal, mainly because of the rapid urbanization and population growth witnessed in recent years. CDCs are faced with the difficulty of managing the substantial volumes of solid waste that are generated. This challenge stems from the fact that many individuals' resort to haphazard dumping as their primary method of handling household solid waste, leading to issues like littering and the accumulation of waste materials (Puopiel, 2010).

Municipal Solid Waste Generation in Liberia

In low-income nations, the average rate of solid waste production per person is typically between 0.4 and 0.6 kg per day, whereas, in fully

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industrialized countries, this rate ranges from 0.7 to 1.8 kg per person per day (Karak et al., 2012). Liberia's four major cities, including Monrovia, Buchanan, Ganta, and Gbarnga, which constitute around 11% of the total population, generate approximately 800 tonnes of solid waste daily (World Bank Report) According to the waste management department of BCC, the city generates approximately 50 metric tonnes of solid waste daily, derived from per capita waste generation data provided by the Liberia Institute of Statistics and Geo-Information Services (Das et al., 2019). In Liberia, unlike more developed nations, there is a lack of pertinent data regarding waste production, making waste management policies reliant on assumptions rather than concrete empirical evidence. The estimation of waste generated is based on the quantity set to be collected, without accounting for uncollected waste. Consequently, conducting a detailed analysis of waste composition at its source and calculating per-person waste generation would facilitate more effective waste management in the urban area. Various public and private groups have formulated nationwide approximations for the speed at which solid waste from municipalities is produced. These approximations are based on average rates of waste generation and do not take into account of differences in income levels and the kinds of businesses and establishments at specific areas (Puopiel, 2010).

Municipal Solid Waste Collection in Liberia

One of the key duties assigned to city corporations, especially Buchanan City Corporation, is the collection and appropriate disposal of waste within their jurisdictions. This approach frequently entails collaboration with the private sector, resulting in the subdivision of municipalities into zones.

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Companies are selected through competitive bidding, although at times, contracts are awarded without a bidding process. Services are provided both with and without formal contractual agreements between these companies and the government. These modes involve the meticulous collection of waste directly from households through door-to-door efforts, predominantly observed in higher socioeconomic neighborhoods. Conversely, communal collection practices are prevalent in lower-income areas. It is important to acknowledge that collection method may not fully address the requirements of underprivileged communities, possibly resulting in subpar waste collection services in these areas. As a result, these regions might not receive adequate attention when it comes to solid waste management, potentially leading residents to resort to unsystematic waste disposal due to the insufficient collection services. This issue extends to communities that lack any form of waste collection services altogether (Das et al., 2019).

Municipal Solid Waste Disposal in Liberia

Over the years, various techniques have emerged for the ultimate disposal of municipal solid waste. These methods differ significantly based on the type of waste and local circumstances (Aleluia & Ferrão, 2016). In the earlier phases of waste management, there were prevalent approaches for disposing of solid waste, such as landfills, canyons, and mining pits; disposal into water bodies; utilization as livestock feed; incorporating waste into the soil through plowing; and reduction and incineration. Reckless dumping on open land and into drainage systems is plainly observable in towns and cities, while coastal towns commonly exhibit the practice of discarding waste into water bodies. This highlights the persistence of solid waste disposal methods

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that have been in use since the 1950s and continue to be utilized to this day. The increasing accumulation of solid waste originating from municipalities and various sources, as well as its subsequent disposal, has emerged as a major concern in Liberia, with particular emphasis on the situation in Buchanan. The central issues primarily revolve around improper waste management practices, including indiscriminate dumping, insufficient disposal sites, challenges in proper waste handling due to deteriorating road infrastructure, and aggravating traffic problems (Das et al., 2019).

Moreover, the capacity limitations of existing dump sites have emerged as a significant challenge for multiple municipalities. Consequently, an urgent need has arisen for the identification and establishment of a new dumping site to address this pressing issue. Due to the inability of established methods for managing solid waste to handle the continuously growing amount of waste produced, there is a tendency to improperly dispose of waste, particularly by discarding it in waterways and drainage passages, as well as resorting to incineration (Yoada et al., 2014). Nevertheless, Idamah (2015) asserted that despite being seen as unhygienic and visually unpleasing, the widespread practice of openly depositing solid waste on land remains the prevailing disposal method.

Involvement with Private Sector in Waste Management

In some Asian cities, the absences in waste service provision stem from insufficient financial resources, inadequate management, and a lack of technical expertise within municipal and governmental bodies, hampering their ability to cope with the rapid surge in service demand.

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Despite constrained budgets, there exists a strong willingness to pay for well-executed services, presenting an opportunity for suitable strategies (Mazigo, 2017). Due to the substantial investments needed, along with continuous operational expenses and the presence of other pressing priorities like water, healthcare, education, roads, and energy, national governments alone often lack the capacity to adequately deliver solid waste services. As a result, there is a growing collaboration between the private sector and the public sector to provide the essential resources required for the effective delivery of solid waste services (Aparcana, 2017).). The government is under pressure to lower taxes and simultaneously enhance service quality. As a result, they are now considering the option of privatizing waste management services. Certainly, here's a revised paraphrase:

Privatization can assume various modalities. A government possesses the authority to allocate contracts to private enterprises for particular MSWM services. Another option involves government collaboration with a private entity in the construction of a waste management facility, which may later become owned or operated by the private entity. Alternatively, the government has the option to grant a license to a private firm to carry out MSWM activities and recover its costs directly from the service recipients. These approaches offer a range of possibilities for structuring partnerships between the public and private sectors to address solid waste management effectively. Furthermore, the option exists for the government to permit eligible corporations to partake in an open competition framework. The public sector might also engage in waste recovery and/or lease the rights to waste recovery to enterprises in the private sector, a proposition put forth (Das et al., 2019).

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CHAPTER THREE

MATERIALS AND METHOD

Research Design

A study design represents the framework, strategy, or method chosen by the researcher to obtain accurate responses to the research query. Its importance lies in providing guidance to the researcher on how to collect and assess data (Atindanbila, 2013). This study utilized a quantitative methodology. As outlined by Cohen et al. (2011), the quantitative methodology streamlines research, expediting the process and rendering it applicable across diverse scenarios. The primary aim of quantitative research is to furnish decision-makers with information that enables them to make educated forecasts about the associations between market conditions and behaviours. It also facilitates gaining substantial insights into these connections while verifying or confirming pre-existing relationships (Creswell, 2012).

On the contrary, this approach can be rigid, overly structured, and ill-suited for assessing the importance individuals place on their actions. Additionally, it does not contribute to the development of theories (Creswell, 2012). The utilization of assessments and surveys enabled the researcher to produce dependable information that could be expressed through statistics and figures, which could then be generalized to a broader population. These factors constituted the primary motives guiding the researcher's choice to employ a quantitative approach.

Due to the study's focus on addressing issues in an area where there might be limited or no prior research, the researcher found it appropriate to

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employ the descriptive survey design. This design is valuable for evaluating aspects such as PCWGR, physical composition, management practices, and institutional frameworks related to MSWM in Buchanan City, Grand Bassa County, Liberia.

The study utilized a Cross-sectional research design, which entails gathering data from participants at a specific point in time. This approach offers the advantage of being manageable, cost-effective, and feasible (Atindanbila, 2013). Descriptive research, often termed as statistical research, aims to provide a comprehensive portrayal of a situation, individual, or event. It also explores relationships between various elements within real-world contexts (Blumberg et al., 2005). Descriptive research effectively addresses questions concerning what, who, how, and when. One of the reasons for opting for a descriptive survey approach was the use of questionnaires in the study. According to Pallant (2001), the descriptive survey design typically involves the utilization of survey instruments like questionnaires.

In Buchanan City, a solid waste audit was conducted across three socio-economic groups to assess both the per capita generation rate and the physical composition of domestic solid waste. Additionally, structured questionnaires were administered to selected households to evaluate their solid waste management practices and to gauge the willingness of community dwellers to pay for improved solid waste collection services within Buchanan City. Moreover, face-to-face were conducted using an interview guide with selected authorities at the Buchanan City Corporation and other key stakeholders to gather qualitative data on existing institutional frameworks and municipal solid waste management practices which provided insights into

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factors influencing improper management of municipal solid waste in the study area.

Description of the Study Area

The study was conducted in the port city of Buchanan, which is also referred to as Gbezohn, the Capital City of Grand Bassa County in Liberia. This captivating location is located on longitude 5° 52' 51" North and latitude 10° 2' 48" West. Buchanan is distinguished for its privileged position adjacent to the expansive Atlantic Ocean, gracing the West Coast of the African continent. This port city holds a distinguished status as the third-largest city in Liberia. This proximity to the boundless oceanic expanse shapes both the city's identity and its historical significance.

According to the National Population and Housing Census (2008), Buchanan has a population of 34,270 inhabitants. Moreover, the name "Buchanan" carries with it a sense of heritage, being named in honour of Thomas Buchanan, an eminent figure who was not only the first governor of Liberia but also held a familial connection to the esteemed American President James Buchanan (LISGIS Census, 2008). Situated at a reasonable distance of approximately 70 miles (110 kilometres) southeast of Monrovia, the capital city of Liberia, Buchanan finds itself situated at a critical juncture. This strategic location places it near the mouth of the Saint John River, contributing to its accessibility and potential for trade and commerce. Notably, fishing takes centre stage as a vital industry that sustains both the local economy and the way of life for many residents in Buchanan. The bounty of the ocean resonates through the city, providing sustenance and livelihood to its inhabitants.

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Additionally, Buchanan boasts of a captivating natural landscape that includes isolated beaches inviting peaceful contemplation and tranquil lagoons that whisper stories of serenity. These natural jewels have remained somewhat hidden, offering a retreat for those who seek solace in the embrace of nature.

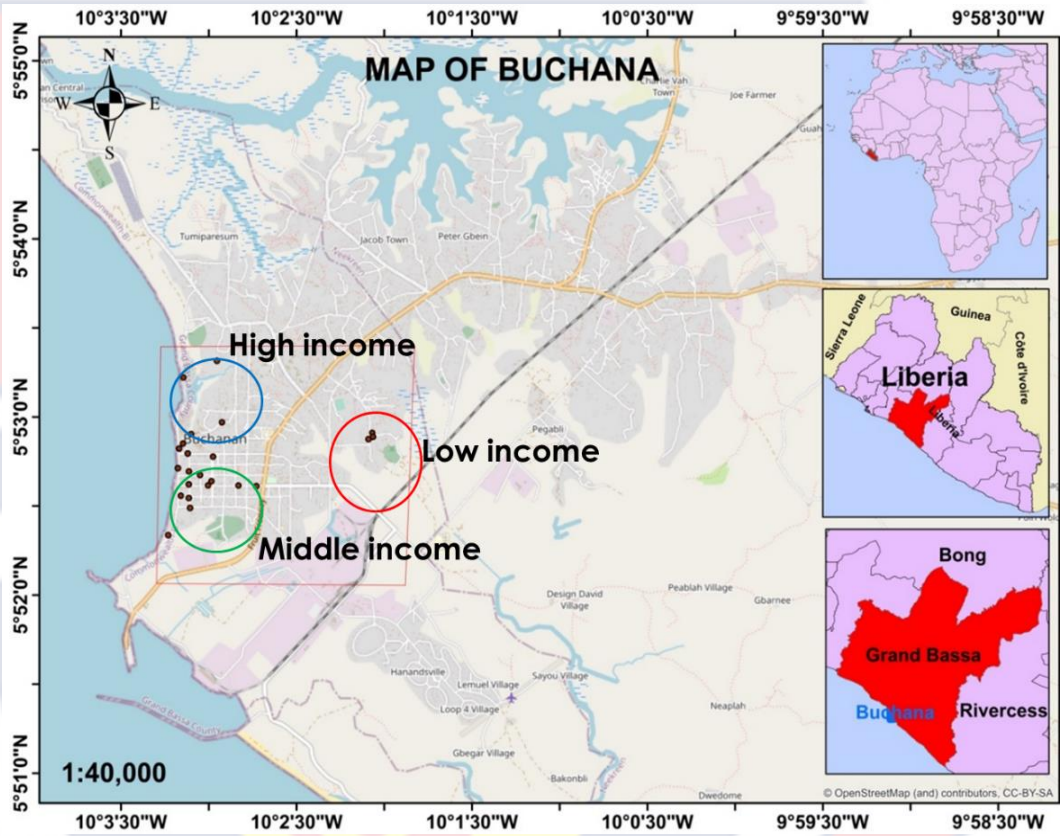

Figure 1: Map of Buchanan Showing the study location.

Study population

According to Yates (2014), a population is the total collection of subjects who satisfy a predetermined set of criteria. The targeted population is made up of people who share an expected characteristic with the overall population (Mugenda & Mugenda 2003). Specifically, it is the targeted population at focus that the researcher emphasised, and the conclusions they can derive from their investigation.

The study encompassed a targeted population of 34,270 individuals residing in Buchanan City between the ages of 18 - 64 years (LISGIS Census,

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2008). This population included a diverse range of individuals such as government employees, private business owners, fishermen, and permanent city residents. The selection of participants from this city was purposeful, based on their varied roles and their exposure to the subject under investigation.

These individuals were specifically chosen due to their potential knowledge concerning municipal solid waste generation, collection, and management in Buchanan City, owing to their prior experiences.

Settlements categorization into socioeconomic areas

The Buchanan City Corporation (BCC) has divided residential neighbourhoods into three primary socio-economic categories, specifically high-income, middle-income, and low-income residential areas. The BCC's classification, rooted in socio-economic development criteria, considers multiple factors such as building types, living standards, and the availability of social amenities within residential areas. Additionally, the Buchanan City Corporation and the Liberian Institute of Statistics and Geo-Information System (LISGIS) regularly evaluate and update the residential classification to ensure that accurate and up-to-date information is available to the public (world bank classification, 2022)

High-income communities

These communities have comparatively good feeder roads, dependable access to social amenities and services like water and electricity, security, well-designed homes with fences, and other social amenities. The homes are typically single- or multi-story detached structures with sizable paved or grassed yards. Despite the prevailing perception that members of this group

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possess significant incomes, there has not been any research conducted to accurately assess the socioeconomic status of these settlers, who typically have smaller family sizes (world bank classification, 2022)

Middle-income communities

According to the world bank classification, 2022, these settlements comprise flats or bungalows as typical buildings. Most of the time, multiple households occupy the structures. The structures are either detached or semi-detached, and they often come with paved courtyards and, occasionally, backyard gardens. Some improvements might have been made to enhance social amenities and services in the area.

Low-income communities

These residential areas suffer from a lack of essential social services and amenities, primarily housing slum-dwelling households. The structures within these areas vary widely, including multi-story buildings, detached structures, and even extremely poor-quality shacks. Other characteristics of these low-income communities include scarce resources, poorly designed housing, high crime and violence, and inadequate educational opportunities (world bank classification, 2022).

Determination of representative sample size for solid waste audit

A well-established statistical technique was employed to estimate the required number of waste samples for analyzing domestic solid waste. This technique was chosen due to the heterogeneity and variability observed in solid waste samples. To determine the necessary sample size for accurately gathering data on per capita within households in Buchanan City, Grand Bassa County, the formula for calculating sample size in the context of continuous

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variable measurement, as proposed and recommended by Cochran (1977), was applied.

The Cochran formula was used to estimate the ideal sample size of waste units by considering factors such as the desired level of precision, confidence level, and the estimated proportion of the element present in the population. This formula is particularly suitable for scenarios involving large populations. However, if the population size is relatively small, a "correction" may be applied to reduce the sample size provided by Cochran's formula. The equation for Cochran's formula is as follows:

$$\square = \frac{\square^{\square}\ \square * \square}{e^{\square}} \quad \textbf{(3)} \quad \text{(Seshie et al., 2020)}$$

Where as, n is the sample size and Z is the value for the chosen alpha level from Z table, which in this study is 1.96 because the desired confidence level is 95%, p and (estimated) proportion of the population that has the characteristic under question, q is (1 – p), e = is the desired margin error (0.05**).**

Based on the formular above, the sample size was calculated as follow**:**

$$\square = \frac{(\square.\square\ \square)^{\square}(\square.\square)^{\square}}{(\square.\square\ \square)^{\square}} = \square\ \square\ \square \qquad \textbf{(4)}$$

Sampling procedure and participant identification

The Nordtest (1995) methodology, commonly utilized in socio-economic area studies, was utilized to calculate the necessary number of households needed to achieve the ideal sample size of 100 to 200 kilograms for the solid waste characterization study. Consequently, thirty-two (32) residents were chosen randomly from each socio-economic area. This methodology has also been consistently applied in analogous research endeavour by Seshie et al. (2020). From the information provided in Table 2, it is evident that the sample

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size utilized the solid waste characterization study exceeded the statistically required sample size. The choice to augment the sample size is consistent with the central limit theorem, which suggests that as the quantity of samples analysed increases, the precision in ascertaining the desired parameters also enhances. Nonetheless, it is vital to guarantee that the amount of solid waste to be examined remains manageable, considering the available of resources and time limitations.

Table 2: Quantity of households selected and the sample size collected for analysis at various income levels within the study area

S/n	Settlement Category	Sampling communities	Number of Selected Households	Required Sample size.	Quantity of samples collected and analyzed
1	High Income	Barcorline	32	385	1792
2	Middle Income	New Buchanan	32	385	1792
3	Low Income	Bardehwleh	32	385	1792

The sampling process involved a systematic selection of households within stratified socioeconomic communities. The necessary sample size and the number of households were predetermined. Within each socio-economic region, households were selected by applying a systematic approach, choosing every fourth house starting from the first house encountered within the sampling area. This approach ensured a systematic and unbiased representation of households across socioeconomic communities.

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Stakeholders' consultation and preliminary site assessment

It was crucial to conduct community entry and preliminary site assessments at each residential area across the three socio-economic groups before commencing the domestic solid waste quantification and characterization study. The community entry phase entailed visiting communities and households selected in Buchanan City for the study. The rationale was to educate the residents and prospective participants on the survey's purpose and underline the importance of their active participation as respondents in the study. The main objective of the field survey was to gather insights into their willingness to engage in the solid waste audit. Respondents were provided with assurances regarding the confidentiality of their provided information. Also, a preliminary site assessment was conducted to evaluate the suitability of the chosen households within the study area for the specific task of waste sorting at its source. Again, ideal locations were demarcated in each socio-economic area for the onsite weighing and sorting exercise.

Per Capita Waste Generation Rate (PCWGR) determination

The methodology for quantifying and characterizing solid waste in this study was adapted from the American Society for Testing and Materials (ASTM D 5231-92), which is a standard test method for assessing the composition of raw municipal solid waste. In this process, chosen households were visited and provided with consistently sized and labelled black polythene bags specifically for the study. Participants were given instructions to gather their daily household solid waste (excluding faeces and hazardous waste) using the supplied black polythene bags. The solid waste produced on the first day was deliberately omitted from the study to prevent any potential

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contamination from waste accumulated in the preceding days. The collection of solid waste samples commenced on the second day and spanned a period of seven days, in accordance with the approach proposed by Donacho et al. (2023). The gathered domestic solid waste samples were weighed on-site using a 15 kg Kinle scale (with the model No PS60, serial No 61183656KK and it was made in china) . Data regarding the daily PCWGR were meticulously documented in Microsoft Excel Spreadsheets for each socio-economic area within the study. To consider daily fluctuations in the PCWGR, the domestic solid waste sampling spanned seven consecutive days across all socio-economic areas (Nadeem et al., 2022). The solid waste audit was conducted a total of eight times over a span of four months, specifically from April to July 2023. Consistency was upheld throughout the study, ensuring uniformity in the sample size, sampling methodology, solid waste components selected for sorting, and the communities chosen for sampling.

Below is the equation for estimating the PCWGR:

$$\text{PCWGR} = \frac{\text{wieght of domestic solid waste generated at household}}{\text{Total number persons in the households x total generation days}} \quad \textbf{(5)}$$

Determination of the physical composition of the domestic solid waste

An ideal surface area was identified with proximity to the final waste disposal site in each socio-economic area. Following the guidelines of the ASTM Standard for determining the composition of unprocessed municipal solid waste, a random subset of 10 waste sample bags was selected from the complete collection of household waste sample bags. This selection aimed to create a representative sample with a minimum size falling within the range of 200 to 300 pounds (91 to 130 kilograms), as advised ASTM for the solid waste characterization study. The ten waste sample bags were emptied onto a 4 mm

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thick black plastic sheet placed on the ground surface. Following the ASTM standard with modifications, the following eight solid waste components were considered for sorting: biowaste, paper, plastic, glass and metals, rubber, inert materials, and miscellaneous items were the eight solid waste components analyzed. To assess the physical waste composition of household in the three socio-economic areas, a combination of coning, quartering, and manual sorting techniques was utilized. The percentage composition of each waste component generated by households was calculated by dividing the total amount of each sorted solid waste component by the overall quantity of mixed solid waste components collected over the eight-week (56-day) study period and then multiplying the result by 100. The procedure was followed in all socio-economic areas under the study.

The equation for the percentage composition is as displayed below:

$$\% \textbf{ Composition of sorted waste} = \frac{\text{wieght of sorted waste}}{\text{The total mixed weight of sample}} \text{ x } 100 \quad \textbf{(6)}$$

Component-specific weighing and sorting were carried out continuously for seven consecutive days, repeated eight times throughout the entire study duration. The results were carefully recorded and organized in separate Microsoft Excel spreadsheets for each of the socio-economic areas that were part of the study.

Questionnaire administration

The Data collection for the research was conducted using three main approaches: conducting a direct field survey, administering questionnaires, and face-to-face interviews. A sampling method involving multiple stages was employed to choose the 500 respondents. To gather relevant data, a meticulously structured questionnaire was devised and distributed

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systematically to selected households. This structured questionnaire aimed to gather information about various aspects of domestic solid waste management pertinent to the research. The survey on household waste characteristics focused on both solid waste management practices and community dwellers' willingness to pay for improved solid waste collection services at the household level. Additionally, the questionnaire aimed to gather details about respondents, the socioeconomic status of their households, methods of waste disposal, awareness of waste separation, understanding of waste management concepts, and familiarity with recycling practices.

The questionnaire's content was formulated around five of the twelve factors that Troschinetz (2005) identified as influential in promoting sustainable solid waste management in developing nations. These factors included waste collection and separation processes, household economic conditions, level of household education, the presence of a local market for recycled materials, and the effectiveness of MSWM administration.

The primary recipients of the questionnaire were women, as they typically oversee tasks related to cleaning, waste collection, and the final disposal of household waste within the home setting. Also, they are always home in the study area while the men normally go to work.

Sample frame and Sample size determination

The Liberia Institute for Statistics and Geo-Information Services (LISGIS) provided a population count of thirty-four thousand, two hundred and seventy (34,270) individuals aged between 18 and 64 for Buchanan City, acting as the reference or basis for the questionnaire survey's sample selection. Moreover,

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the sample size for the survey was determined using the Slovin formula as depicted for the questionnaire survey.

$$n = \frac{N}{1+Ne^2} \qquad (7)$$

Where: n is the desired sample size, N is the sample frame (34,270), and e represented the margin of error which is **0.05** which is significant for social and educational research as reported by Ismail et al. (2022) with a confidence level of **95%.**

$$n = \frac{34{,}270}{1-34{,}270\ (0.05)2} = 400 \qquad (8)$$

However, the required sample size of 400 respondents as estimated above was increased to 500 respondents to satisfy the central limit theorem. Therefore, 500 respondents were used for the questionnaire survey.

Sampling technique for questionnaire administration

Various sampling methods were utilized to choose participants for the research. These sampling methods included cluster, purposive, systematic, and accidental sampling. Initially, the study region was divided into three clusters: North Zone, Central Zone, and South Zone. A total of fourteen (14) areas were purposefully selected from these three sub-zones of Buchanan City for the questionnaire survey as depicted in Table 3 below.

Table 3: Sub Zones and Selected Areas of the Survey (Cluster Sampling)

Sub Zones	Selected communities	Total
North	Big Fanti town, Old Field, Moore town, Bardehwleh	4
Central	Open Bible, Sawmill, Corn farm, Biafra, Field ground, Barcorline	6
South	New Buchanan, Gorzohn, Christian High, Saye-pue Hill	4
Total		14

Author's construct (2023)

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Due to insufficient census data available regarding the female population in Buchanan City, the sample size of 500 participants was distributed across the 14 chosen areas, considering the data obtained from the community chairpersons on the current number of houses in each of the selected communities. A systematic sampling approach was employed to pick households within each of these chosen areas. The systematic sampling process is outlined in Table 4 below.

Additionally, because the houses in the selected areas lacked proper sequential numbering, a serpentine movement approach was adopted. This approach involved choosing every Kth house, starting from the first house encountered within the designated area. This process was repeated until all the predefined respondents were interviewed within each area, achieving the desired sample size.

Lastly, the accidental or convenience sampling technique was implemented to choose participants for the questionnaire survey. This involved interviewing the first adult (above 20 years) encountered in each selected household. In cases where the initial adult approach was unavailable, the subsequent accessible adult was interviewed depending on their affiliation with the specific household. As a portion of the respondents had difficulty understanding English, individuals proficient in both English and the local dialect were trained and engaged to conduct the questionnaire sessions. To ensure effectiveness, the questionnaires was pre-tested on small amount of people within the study area prior to the complete survey being conducted.

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Table 4: Systematic Sampling of Respondents

Selected Community	No. of Houses (Sampling frame)	Total respondents to be surveyed (Sample size)	Sample fraction (Kth house)
Big Fanti town	164	30	Every 4th house
Old Field	236	40	Every 7th house
Moore town	194	40	Every 4th house
Bardehwleh	248	40	Every 6th house
Open Bible	186	40	Every 4th house
Sawmill	236	40	Every 6th house
Corn farm	126	30	Every 5th house
Biafra	86	30	Every 3rd house
Saye-pue Hill	103	30	Every 4th house
Christian High	97	30	Every 3rd house
New Buchanan	156	40	Every 6th house
Gorzohn	117	30	Every 4th house
Barcorline	320	40	Every 8th house
Field ground	264	40	Every 7th house

Source: Author's construct

Data processing and analysis

Quantitative and Qualitative data collected from the survey conducted in the study area were analyzed utilizing charts, averages, ratios, and percentages. This analysis was facilitated through the use of Statistical Package for Social Science (SPSS version 23) for Windows and Microsoft Excel. To evaluate if there were statistically significant differences in the rates of waste generation between the three settlement groups, a one-way ANOVA was performed. The level of significance was 0.05 with a 95% confidence interval. The linear Regression was conducted to link the socio demographic data with the responses from the respondents.

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Ethical consideration

When one wants to properly do research, ethical issues are quite important. Basically, confidentiality, informed consent, and anonymity are the primary ethical issues considered in this research. Considering confidentiality, all reasonable measures were taken to preserve the confidentiality of the respondent's responses. In other words, the participants were given the assurance that their responses would be treated as confidential and that no identifiable external entity or persons would be able to access the information they would provide. Additionally, informed consent was approved by respondents. That is, the opportunity was given to the respondents to accept or decline from partaking in the study. Inform consent outlines the necessity for respondents to comprehend the primary goal, objective, and possible adverse effects before deciding whether they want to engage in the research (Seidman, 2006). Before distributing the questionnaire to the participants, the researcher provided a clear explanation of the research objective. Ethical clearance was obtained from the University of Cape Coast prior to the commencement of the study.

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CHAPTER FOUR

RESULTS

This chapter presents the findings of the study. It highlights the solid waste generation rate per capita, physical composition of solid waste, demographic characteristics, municipal solid waste management practices, and solid waste management strategies.

Physical Composition of Domestic Solid Waste in Buchanan City

The primary domestic solid waste components identified through the study are organics, plastics, paper, metals, rubber, textiles, inert materials, and miscellaneous items such as within eight weeks between the months of April and August of 2023, a total cumulative waste of 5596.5 kg of waste was collected and weighed in the three distinct socio-economic zones within Buchanan City, Grand Bassa County. The data analyses reveal the mean of physical waste composition for household solid waste across the entire spectrum of three socio-economic groups and the various waste components across the three socio-economic groups. Among the cumulative wastes, the low-income community contributed 1296.8 kg, the middle-income area provided 2342.4 kg, and the high-income area yielded 1957.3 kg and across the various waste components in three socio economic groups, organic waste comprised 373.0 of the waste stream, while paper constituted 285.6 plastics accounted for 268.9,metals represented 185.5, textiles constituted 292.0, and rubber contributed 63.5. Inert materials and miscellaneous items made up 191.1 and 232.8 respectively (as detailed in Table 5).

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Table 5: Physical Composition of domestic solid waste across the three Socio-economic areas

Physical composition of waste	Socio-economic Groups							
	Barcorline - High Income		New Buchanan- Middle Income		Bardehwleh- Low Income		Overall Average	
	Wt. kg	Wt %	Wt. kg	Wt %	Wt. kg	Wt %	Wt. kg	Wt %
Organics	583.8^{ab}	29.8	346.2^{cd}	14.8	189.1^{cd}	14.6	373.0	19.7
Paper	428.2^{bd}	21.9	213.0^{bf}	9.1	134.6^{cf}	10.4	258.6	13.8
Plastics	114.0^{ae}	5.8	478.0^{be}	20.4	214.7^{ce}	16.6	268.9	14.3
Metal	284.3^{mn}	14.5	175.3^{ez}	7.5	97.1^{kd}	7.5	185.5	9.8
Textile	250.6^{az}	12.8	437.9^{ma}	18.7	187.5^{bz}	14.5	292.0	15.3
Rubber	54.3^{ao}	2.8	68.2^{ob}	2.9	68.2^{ob}	5.3	63.5	3.6
Inert	107.4^{ek}	5.5	293.0^{nc}	12.5	173.0^{nc}	13.3	191.1	10.4
Miscellaneous	134.6^{am}	6.9	331.0^{ck}	14.1	232.7^{ck}	17.9	232.8	13.0
Total	1957.3	100.0	2342.4	100.0	1296.8	100.0	1865.5	100

Means for total weight in rows with the same letter superscripts are not significantly different ($p > 0.05$), whereas means for total weight in rows with different letter superscripts are significantly different ($p < 0.05$).

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Table 6 shows the variation in material composition between the low- and middle-income levels, analysis of variance was applied to the means of the waste fractions.

Table 6: Comparison of Material Composition between Low- and Middle-Income Groups using One way ANOVA

Material Composition	Middle-Income	Low-Income	F-value F (1, 14)	P-value
Organics	346.21	189.12	464.48	0.00
Paper	213.01	134.62	241.95	0.00
Plastics	477.97	214.68	524.18	0.00
Metals	175.26	97.11	185.78	0.00
Inert	437.85	187.46	3.21	0.09
Rubber	68.15	68.16	0.15	0.71
Textiles	293.04	172.95	166.8	0.00
Miscellaneous	330.95	232.69	30.64	0.00
Total	2,342.44	1,206.79	1,617.19	0.8

The result indicates that inert (F (1, 14) =3.21; p = 0.09) and rubber (F (1, 14) = 0.15; p = 0.71), exhibited no statistically significant difference in the waste fraction generated. Conversely, organics (F (1, 14) = 464.48; p = 0.00), paper (F (1, 14) = 241.95; p = 0.00), plastics (F (1, 14) = 524.18; p = 0.00), metals (F (1, 14) = 185.78; p = 0.00), textiles (F (1, 14) = 166.8; p = 0.00), and Miscellaneous (F (1, 14) = 30.64; p = 0.00).

Table 7 shows the variation in material composition between the low- and high-income levels, analysis of variance was applied to the means of the waste fractions.

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Table 7: Comparison of Material Composition between Low- and High-Income Group using One-way ANOVA

Material Composition	Low-Income	High - Income	F-value F (1, 14)	P- value
Organics	189.12	583.81	814.33	0.00
Paper	134.62	428.23	2586.74	0.00
Plastics	214.68	114.00	122.18	0.00
Metals	97.11	284.26	908.4	0.00
Inert	187.46	250.61	5.55	0.03
Rubber	68.16	54.30	13.20	0.00
Textiles	172.95	107.44	66.44	0.00
Miscellaneous	232.69	134.64	30.74	0.00
Total	1296.79	1957.29	4547.58	0.03

The result indicates that significant variation exist in all material composition across the two income levels (low and high income), with organics ($F(1, 14) = 814.33$; $p = 0.00$), paper ($F(1, 14) = 2586.74$; $p = 0.00$), plastics ($F(1, 14) = 122.18$; $p = 0.00$), metals ($F(1, 14) = 908.4$; $p = 0.00$), inert ($F(1, 14) = 5.55$; $p = 0.03$), rubber ($F(1, 14) = 13.20$; $p = 0.00$), textiles ($F(1, 14) = 66.44$; $p = 0.00$), and Miscellaneous ($F(1, 14) = 30.74$; $p = 0.00$).

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Th variation in material composition between the middle- and high-income groups, and the results of the analysis of variance are as shown in Table 8 below.

Table 8: Comparison of Material Composition between Middle- and High-Income group by One-way ANOVA

	Middle-Income	High -Income	F-value F (1, 14)	P-value
Organics	346.21	583.81	285.16	0.00
Paper	213.01	428.23	1219.32	0.00
Plastics	477.97	114	1974.57	0.00
Metals	175.26	284.26	296.68	0.00
Inert	437.85	250.61	2.54	0.13
Rubber	68.15	54.3	26.01	0.00
Textiles	293.04	107.44	496.76	0.00
Miscellaneous	330.95	134.64	276.38	0.00
Total	2342.44	1957.29	4577.42	0.13

The result indicates that significant variation exist in material composition across the two income levels (middle and high income), with organics ($F(1, 14) = 285.16$; $p = 0.00$), paper ($F(1, 14) = 1219.32$; $p = 0.00$), plastics ($F(1, 14) = 1974.57$; $p = 0.00$), metals ($F(1, 14) = 296.68$; $p = 0.00$), rubber ($F(1, 14) = 26.01$; $p = 0.00$), textiles ($F(1, 14) = 496.76$; $p = 0.00$), and Miscellaneous ($F(1, 14) = 276.38$; $p = 0.00$).

Table 9 shows the relationship (significant difference) exiting between material composition, for the fractions of waste generated across the three income levels (high, middle, and low), analysis of variance (one-way Anova single factor) was performed on the means of the various waste materials.

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Table 9: ANOVA for Material Composition Across Income Groups for Waste Fractions

Waste Composition	F – Value	*p* – value
	F (2, 21)	
Organics	535.52	0.00
Paper	1433.85	0.00
Plastics	750.72	0.00
Metals	475.55	0.00
Inert	2.88	0.08
Rubber	9.745	0.00
Textiles	241.20	0.00
Miscellaneous	75.33	0.00

Per capita waste generation rate in Buchanan City

Table 10 illustrates the PCWGR across the three distinct socio-economic income areas within Buchanan City, Grand Bassa County, Liberia. The high-income area displayed the highest PCWGR, registering at 0.84 kg/capita/day. Following closely, the middle-income and low-income areas displayed rates of 0.36 kg/capita/day and 0.34 kg/capita/day, respectively. On average, the combined PCWGR for all three socio-economic areas stood at 0.51 kg/capita/day.

Table 10: Per Capita Waste Generation Across Income Levels

S/N	Income Group	Per Capita kg/capita/day
1	High	0.84
2	Middle	0.36
3	Low	0.34

Table 11 shows the means for Per Capita Waste Generation in rows with the same letter superscripts are not significantly different ($p > 0.05$), whereas

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means for Per Capita Waste Generation in rows with different letter superscripts were significantly different ($p < 0.05$).

Table 11: Per Capital Waste Generation at Different Income Levels

Period	High Income kg/capita/week	Middle Income kg/capita/week	Low Income kg/capita/week
Week 1	579.05^{cd}	383.02^{ab}	399.9^{ab}
Week 2	542.42^{mn}	426.29^{ef}	410.19^{ef}
Week 3	585.38^{ob}	398.28^{ck}	406.7^{ck}
Week 4	589.33^{cf}	432.8^{sk}	413.59^{sk}
Week 5	559.32^{bd}	404.16^{zn}	426.5^{zn}
Week 6	579.05^{em}	357.2^{cv}	399.9^{ns}
Week 7	542.42^{df}	398.28^{wn}	346.09^{um}
Week 8	582.92^{ec}	313.8^{ko}	422.06^{bn}
Total	4559.89	3113.83	3224.93

Demographic Information of Respondents

Table 12 indicates the demographic information of respondents. The study included 500 individuals from Buchanan City, with a gender distribution leaning slightly towards females, who represented 53%, compared to males at 47%. The age factor offered additional insights; 55% of respondents fall within the 18-27 age bracket, followed by 20% in the 28-37 age range. Seventy-one per cent (71%) of the respondents were single, eighteen percent (18%) were married, five per cent (5%) were divorced, and four percent (4%) were separated.

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Table 12: Demographic information of respondents

Variable	Frequency (N)	Percent (%)
Gender		
Male	234	47
Female	266	53
Total	500	100
Marital status		
Single	357	71
Married	88	18
Divorced	23	5
Separated	20	4
Widowed	12	2
Total	500	100
Age range		
18 – 27	276	55
28 – 37	101	20
38 – 47	59	12
48 – 57	29	6
58 and above	35	7
Total	500	100
Religion		
Christianity	420	84
Islam	57	11
Traditional practice	23	5
Total	500	100
No. of persons in household		
1 – 3	58	12
4 – 6	154	31
7 – 9	137	27
10 and above	151	30
Total	500	100
No. of years lived in community		
0 – 4	198	40
5 – 9	128	26
10 – 14	85	17
15 and above	89	18
Total	500	100
Level of education		
Never schooled	56	11
Primary education	7	2
Junior high education	12	2
Senior high education	72	14
University	353	71
Total	500	100
Occupation status		
Employed	91	18
Unemployed	151	30
Self-employed	182	36
Trader	27	6
Farmer	4	1

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Student	45	9
Total	500	100
Income level range		
$50 – 150	255	51
$150 – 250	46	9
$250 – 350	13	3
$350 – 450	8	2
$450 – 550	21	4
$550 – 650	13	3
$650 – 750	13	3
N/A	131	26
Total	500	100

Predicting Willingness to Pay for Solid Waste Management Services using selected socio demographic factors

Table 13 presents the correlation between the dependent and independent variables is shown by the R-value. For example, if R > 0.4, the model is chosen for additional analysis. In this instance of the dependent variable: willingness to pay for solid waste management services examined by predictor: gender, ($R = 0.110^{a}$) is poor, since R< 0.4 the predictor does not have an influence on the dependent variable.

Using R-square, one can see how much of the total variation in the dependent variable, the independent variable (predictor) can account for. The model is effective enough to identify the association when $R^2 > 0.5$. In this model ($R^2 = 0.012 < 0.5$) is poor, thus total variation in the dependent variable: willingness to pay for solid waste management service could not be examined by predictor: gender. Hence this model is not effective enough to identify the relationship between payment for SWM services and gender.

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Table 13: Beta regression values with corresponding t-values for Predictors

Model	Unstandardized Coefficient		Standardized Coefficient	T	Sig
	B	Std Error	Beta		
Const.	9.639	0.383		216.884	0.00
Gender	0.092	0.037	**0.110**	**2.464**	0.014
Marital Status	-0.033	0.02	-0.073	-1.635	0.103
Age Range	-0.004	0.015	-0.011	-0.252	0.801
Religion	-0.024	0.037	-0.029	-0.651	0.515
No of Persons in household	0.003	0.019	0.008	0.176	0.861
Level of Education	-0.001	0.014	-0.002	-0.051	0.960
Income level Range	0.013	0.012	0.056	1.081	0.280

Methods of waste disposal

Figure 2 indicates the methods of waste disposal, in stark contrast, environmentally friendly methods like composting are scarcely adopted, with only 0.6% of the sample practicing it, possibly due to limited awareness or urban space constraints. An even smaller fraction, 0.4%, combines burning with burying, a method that can lead to soil contamination.

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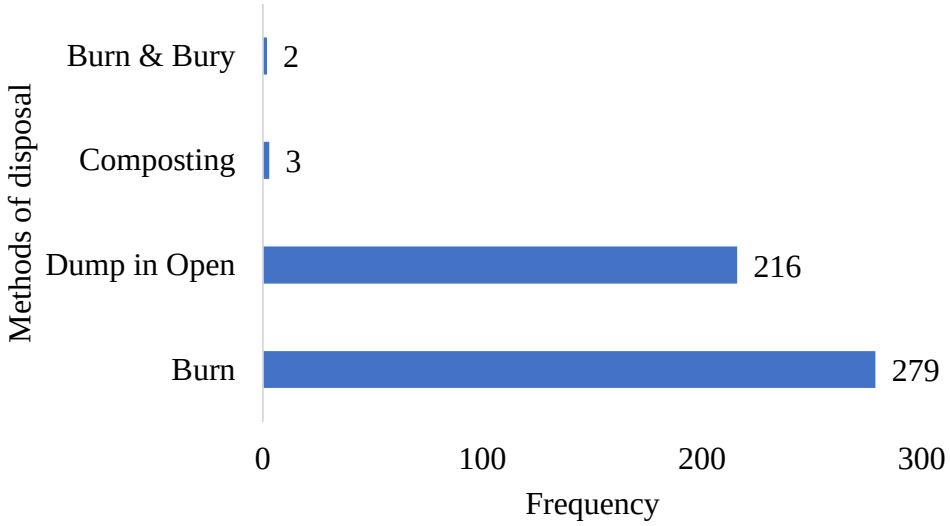

Figure 2: Methods of waste disposal

Designated area for solid waste disposal

Most of the respondents in addition stated that they have designated locations for waste disposal as depicted in Figure 3. Of the respondents surveyed, 51.6% confirmed having designated areas for waste disposal, while 48.4% indicated the absence of such areas.

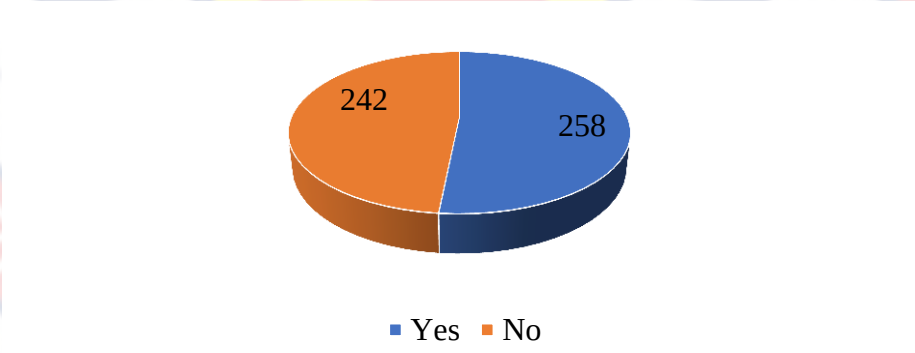

Figure 3: Designated area for solid waste disposal

Waste Collection and temporary storage system

The methods employed by residents for pre-collection or temporary storage of waste provide insight into their immediate waste-handling practices. The findings are presented in Figure 4. Majority of the respondents (312,

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representing 62.4%) use old buckets for the pre-collection and temporary storage of waste followed by plastic bags, (13.8%), interestingly, old drums and individual plastic container are equally preferred, each accounting for (8.8%) and metal bins, (5%). A small fraction percentage, 1% of the respondents use rice bags to store their waste.

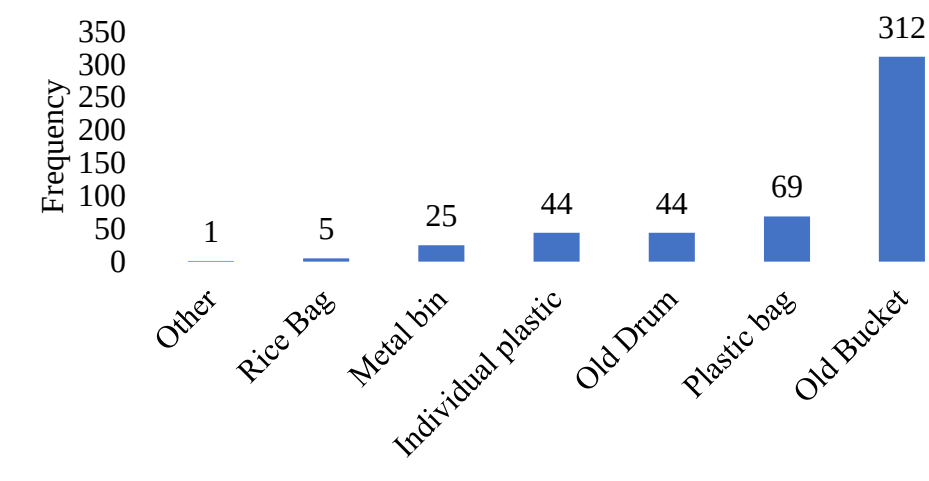

Figure 4: Methods of pre-collection and temporary storage of waste

Presence of waste collection system

In the surveyed population, as shown in figure 5, a concerning 74.6% (373 out of 500 respondents) indicated the absence of a collection system from their yards after temporary storage and conversely, only 25.4% (127 respondents) benefit from a formal collection system, indicating that they have access to a more structured and organized waste disposal process.

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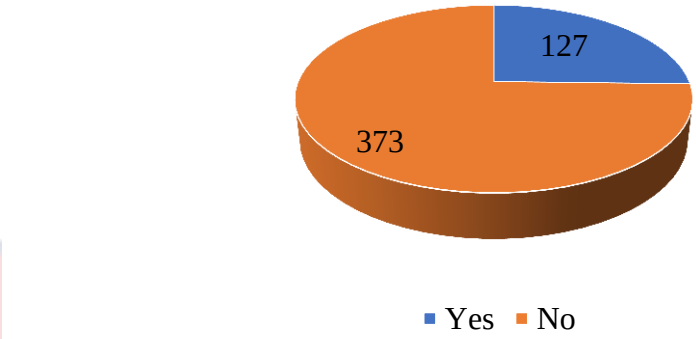

Figure 5: Presence of waste collection system

Institutions responsible for solid waste collection

Figure 6 shows institutions responsible for solid waste collection. The majority, at 58.3% (74 out of 127 respondents), identified the Buchanan City Corporation (BCC) as their primary waste collector. Meanwhile, 40.2% (51 respondents) rely on private collectors, Notably, only a minimal 1.6% (2 respondents) identified the Environmental Protection Agency (EPA) staff as their waste collectors.

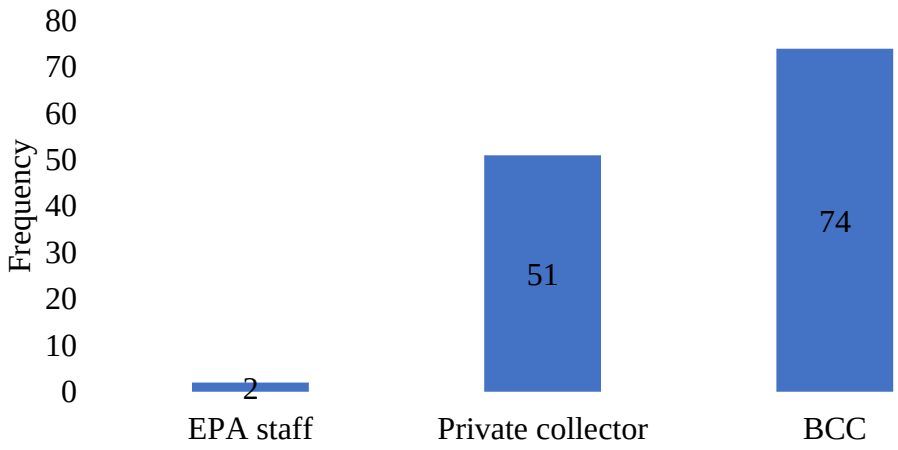

Figure 6: Institutions responsible for solid waste collection

Frequency of private waste collection services

In assessing the frequency of waste collection by private service providers, a majority of 53 out of 127 respondents (41.7%) indicated that their

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waste is collected on a weekly basis figure 7. Notably, 33 respondents (26%) experience daily collections, which could be attributed to higher waste generation rates in certain areas or the efficiency of specific private providers. Twice-a-week collections serve 20 respondents (15.7%), offering a middle-ground frequency, possibly catering to households with moderate waste production. Interestingly, 14 respondents (11%) distinguished between "Every Day" and "Daily" collections. A smaller fraction, of 7 respondents (5.5%), reported waste collection "Every other day.

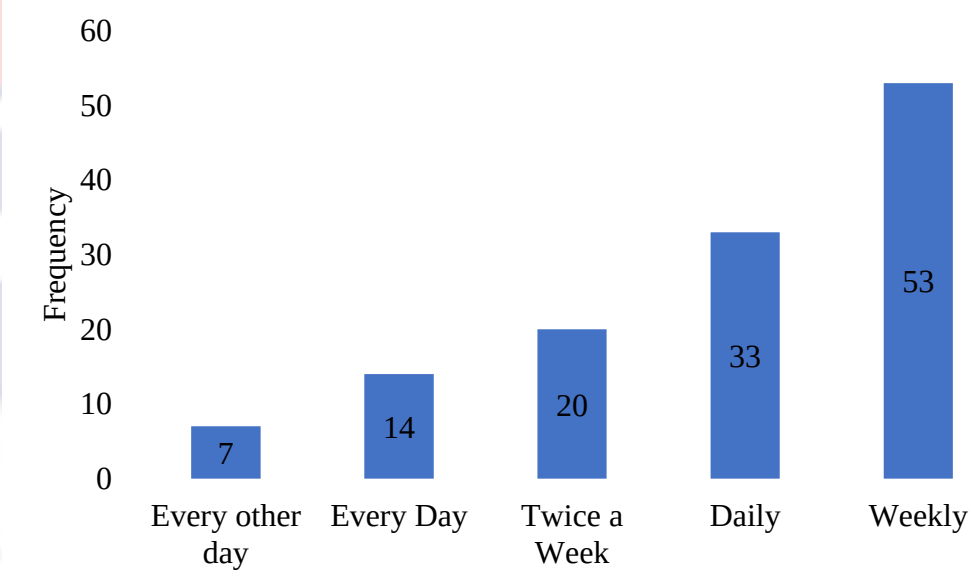

Figure 7: Frequency of private waste collection services

Rating of private solid waste collection services

As shown in Figure 8 a notable 31 out of 127 respondents (24%) deemed the service as "Excellent," indicating high satisfaction and reliability associated with these private entities. Meanwhile, 47 respondents (37%) rated the service as "Satisfactory," and 49 respondents (39%) rated the service as "Poor."

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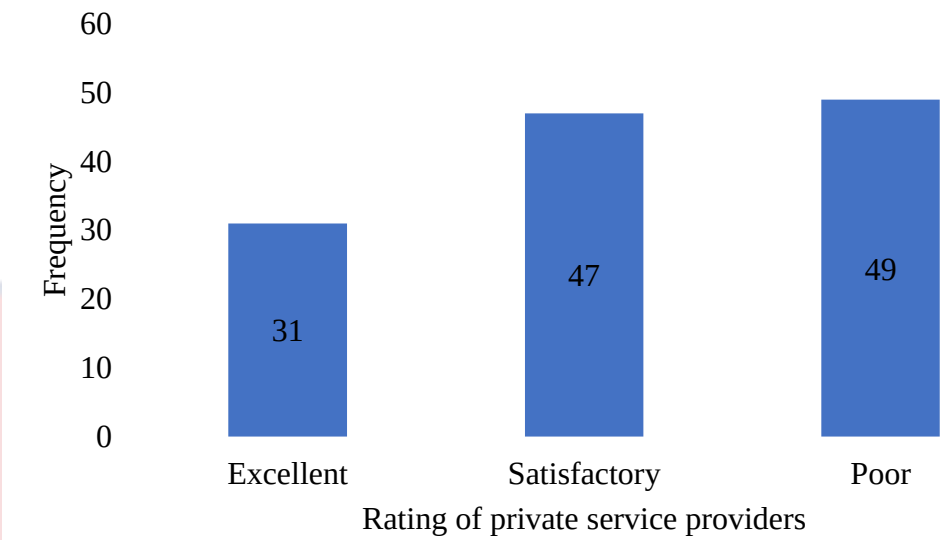

Figure 8: Rating of private solid waste collection services

Use of waste for Fertilizer and Energy Production

The unanimous response from the surveyed population regarding the utilization of food and vegetable wastes is strikingly clear. All 500 respondence (100%) expressed a willingness to use their food and vegetable wastes for fertilizer production.

Availability of infrastructure for solid waste disposal

Evaluating the accessibility of public waste disposal facilities, a significant majority of respondents, 390 out of 500 (or 78%) reported the absence of public bins or communal areas for waste disposal in or near their community, conversely, only 22% (or 110 respondents) confirmed that only a fraction of the community has easy access to structured waste disposal points as shown in figure 9.

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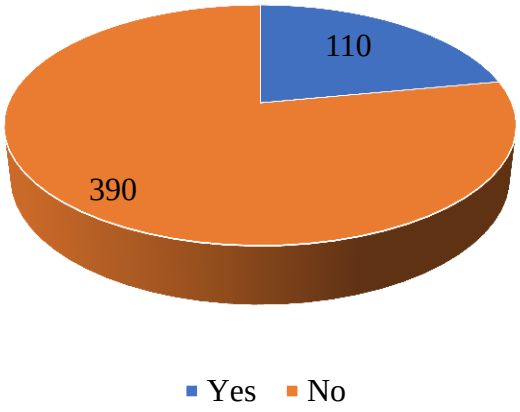

Figure 9: Availability of bins for solid waste disposal

Frequency of Empty Bins

As shown in figure 10, the most common frequency reported was "Once a week," with 32 out of 110 respondents (or 29%) indicating this schedule. This suggests a structured, albeit potentially insufficient, waste collection routine for some areas. "Twice a week" was the next most common response, cited by 29 respondents (or 26.4%), indicating a slightly more frequent service for certain localities as shown in Figure 10. Less common were "Everyday" and "Thrice a week" frequencies, reported by 14 (or 12.7%) and 10 respondents (or 9.1%) respectively. Notably, 25 respondents (or 22.7%) were unsure about the emptying frequency.

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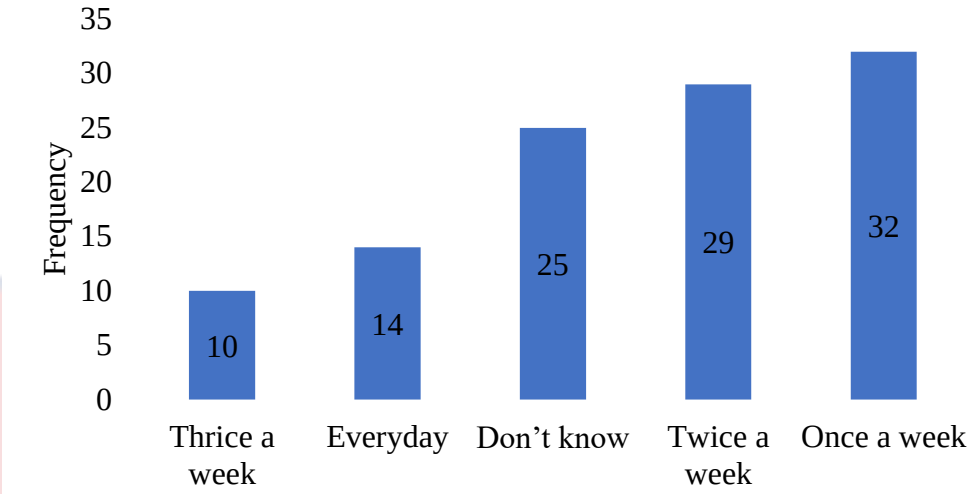

Figure 10: How often are the bins emptied?

Size of solid waste bins

A significant portion of the respondents, 74 out of 110 (or 67.3%), felt that the bins were not large enough to accommodate the waste generated as shown in Figure 11. Conversely, only 36 respondents (or 32.7%) believed the bins to be of adequate size.

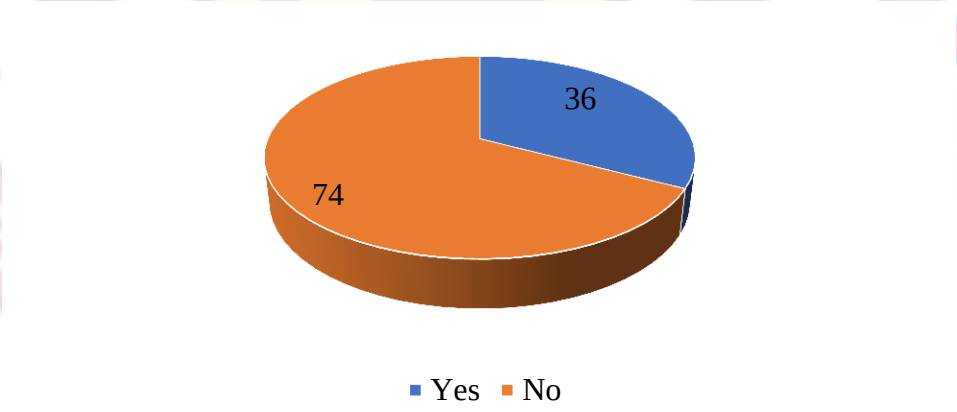

Figure 11: Size of solid waste bins

Waste Management Strategies

As illustrated in figure 12, a substantial of 356 out of 500 respondents (or 71.2%) indicating that individuals are predominantly responsible for their

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own waste, On the other hand, the Buchanan City Corporation (BCC) appears to play a significant role in waste management, with 92 respondents (or 18.4%) identifying them as the primary entity overseeing waste. Fifty-one (51) respondents (or 10.2%) highlighted community-driven initiatives, with only a singular respondent (or 0.2%) identifying a private entity as overseeing waste.

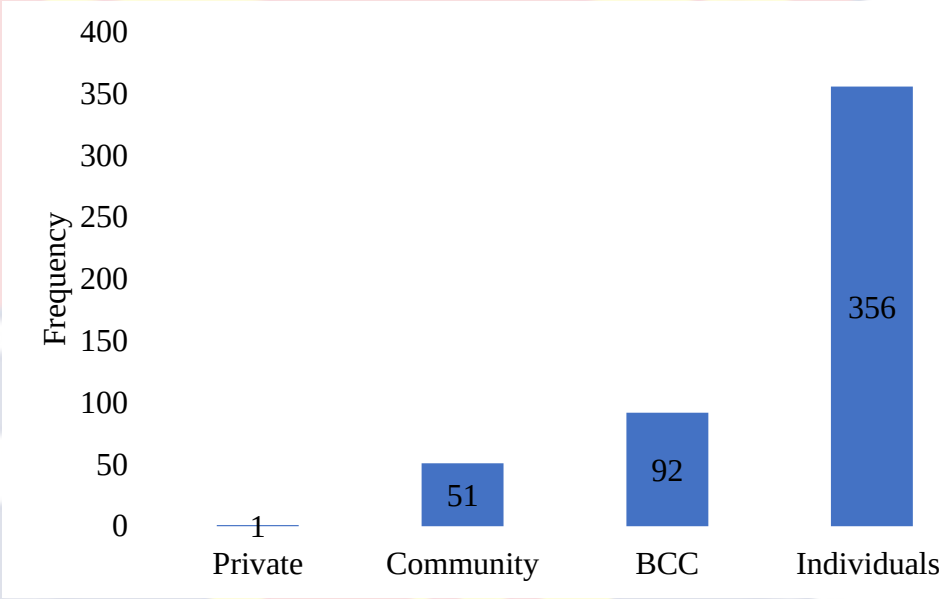

Figure 12: Institution in charge of solid waste management

Awareness of waste management strategies

A significant majority, 425 out of 500 respondents (or 85%), indicated their awareness of waste management strategies as illustrated in Figure 13. Conversely, 75 respondents (or 15%) reported a lack of awareness, pointing to a segment of the population that might benefit from targeted educational efforts.

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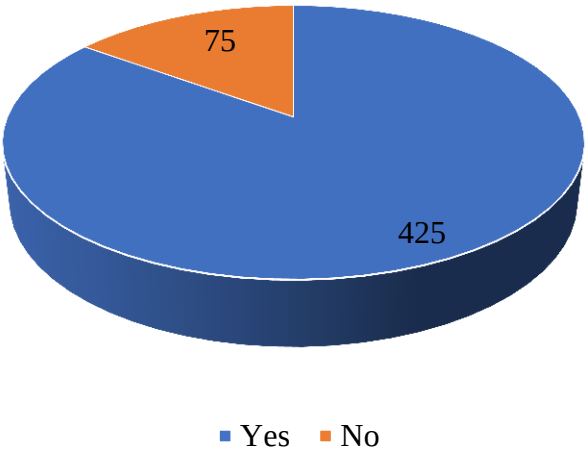

Figure 13: Awareness of waste management strategies

Solid waste management strategies

Figure 14 shows the solid waste management strategies. Overwhelmingly, 423 out of 500 respondents (or 84.6%) identified dumpsites as the primary method being promoted. On the other end of the spectrum, a mere 2 respondents (or 0.4%) indicated the promotion of the "Waste to Energy" method. Incineration was noted by 33 respondents (or 6.6%), burying, a method identified by 27 respondents (or 5.4%), is a step above open dumping, and Composting was recognized by 15 respondents (or 3%). Incineration was noted by 33 respondents (or 6.6%), burying, a method identified by 27 respondents (or 5.4%), is a step above open dumping, and Composting was recognized by 15 respondents (or 3%).

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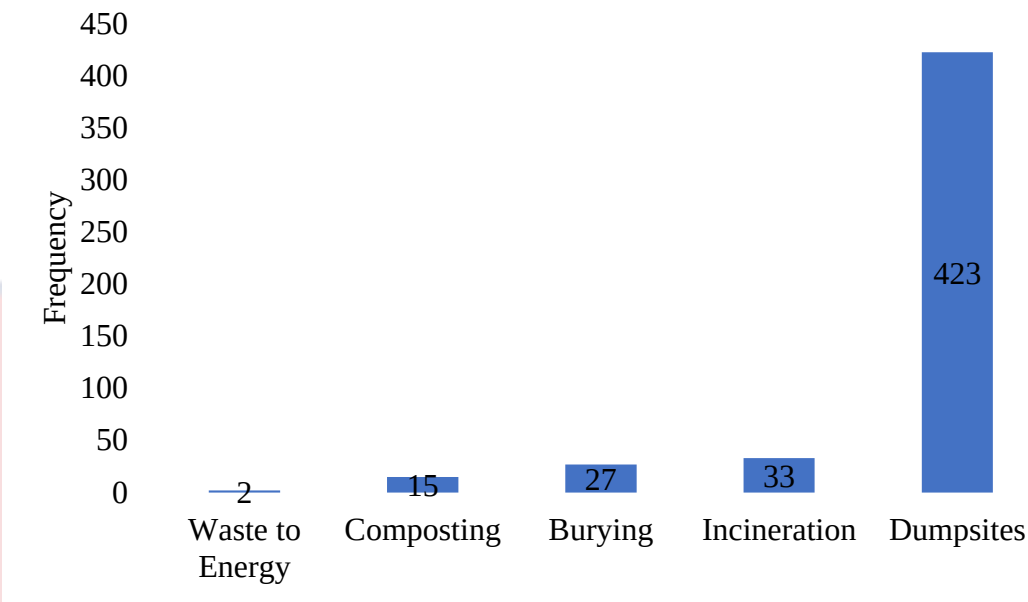

Figure 14: Solid waste management strategies

Common solid waste management strategies

As illustrated at Figured 15, dumpsites, recognized by 242 out of 500 respondents (or 48.4%), emerge as the most common strategy. Burning and burying are also notably common, with 122 (or 24.4%) and 116 (or 23.2%) respondents identifying these methods respectively.

Incineration was noted by 12 respondents (or 2.4%), Composting, an environmentally-friendly approach to repurposing organic waste was indicated by 6 respondents (or 1.2%).

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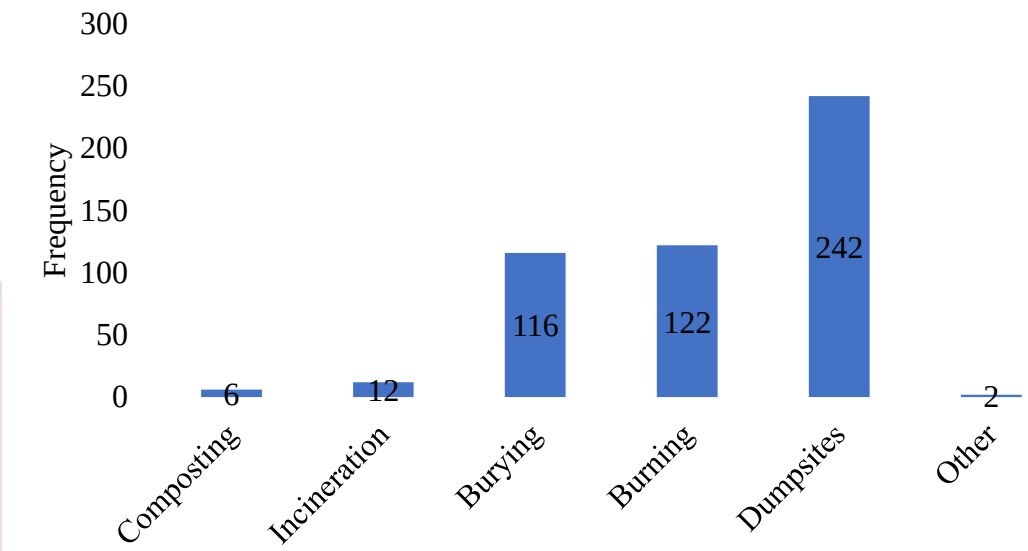

Figure 15: Common solid waste management strategies

Challenges in solid waste management

As illustrated in figure 16 a staggering 426 out of 500 respondents (or 85.2%) identified the inadequacy of waste bins as a primary concern. Close to this, 36 respondents (or 7.2%) pointed out the infrequency of waste collection as a challenge and a lack of waste bins altogether was reported by 34 individuals (or 6.8%). Interestingly, only a small fraction, 4 respondents (or 0.8%), cited expensive waste collection bills as a challenge.

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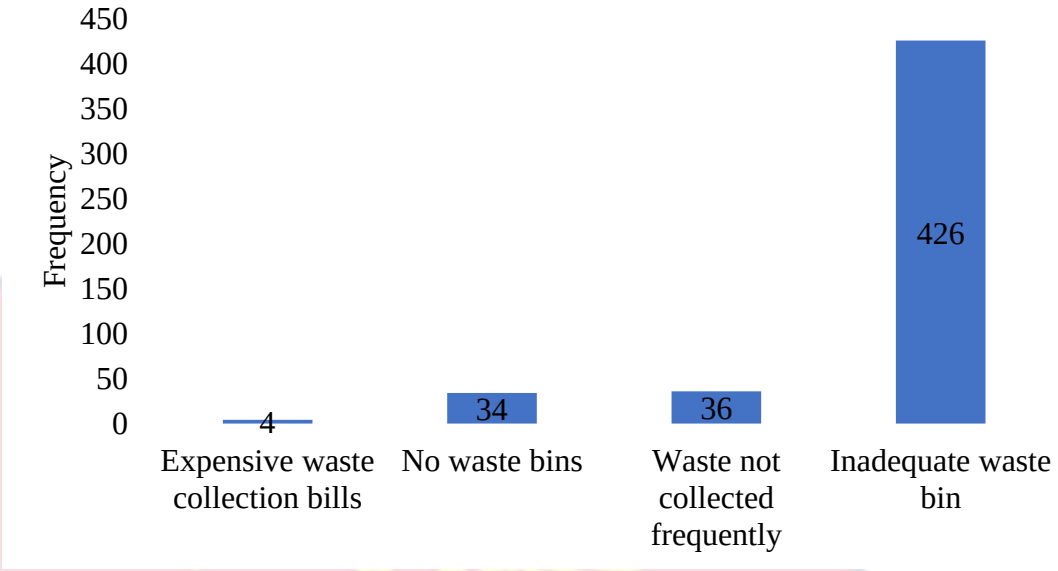

Figure 16: Challenges in solid waste management

Willingness to pay for improved wastes management services.

As shown in figure 17, a vast majority of respondents, 428 out of 500 (or 85.6%), reported the absence of a payment system for waste collection. Conversely, only 72 respondents (or 14.4%) confirmed the presence of a payment system.

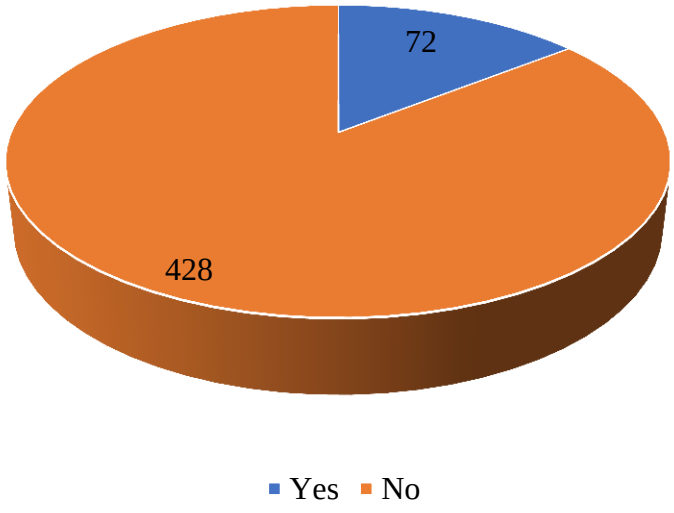

Figure 17: System of payment for waste collection

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Frequency of payments of waste collection

Figure 18 shows the frequency of payments that was identified by 46 out of 72 respondents (or 63.9%) as the primary entity that pay for waste services. However, a notable portion, 25 respondents (or 34.7%), reported paying "Street boys," and interestingly, only one respondent (or 1.4%) mentioned paying the "Community Head.

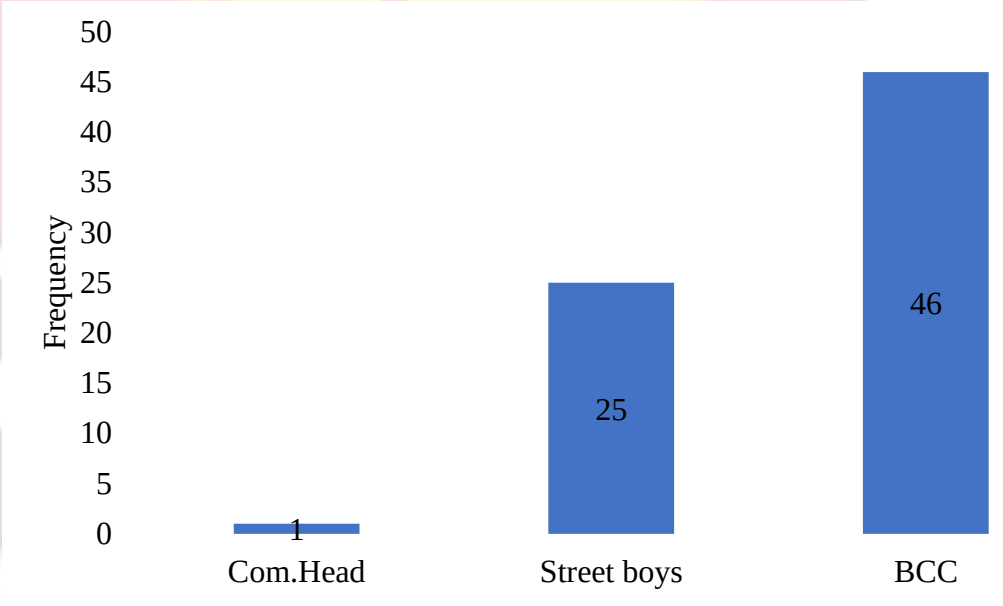

Figure 18: Payment of waste collection

Willingness to pay for solid waste collection service

Figure 19 shows the willingness to pay for solid waste collection service. A substantial 388 out of 500 respondents (77.6%) expressed their willingness to pay for waste collection, and conversely, 112 respondents (22.4%) were not willing to pay, suggesting potential financial constraints.

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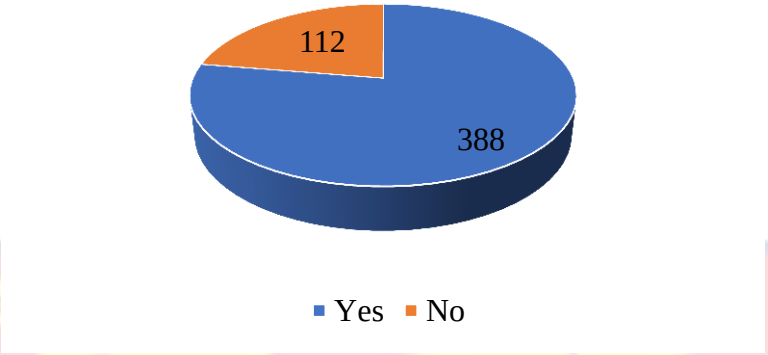

Figure 19: Willingness to pay for solid waste collection service

Amount respondents are willing to pay.

As shown in figure 20, the majority, with 167 out of 388 respondents (or 43.1%), indicated a willingness to pay $10, comprising 123 respondents (or 31.7%), and was willing to pay $5.

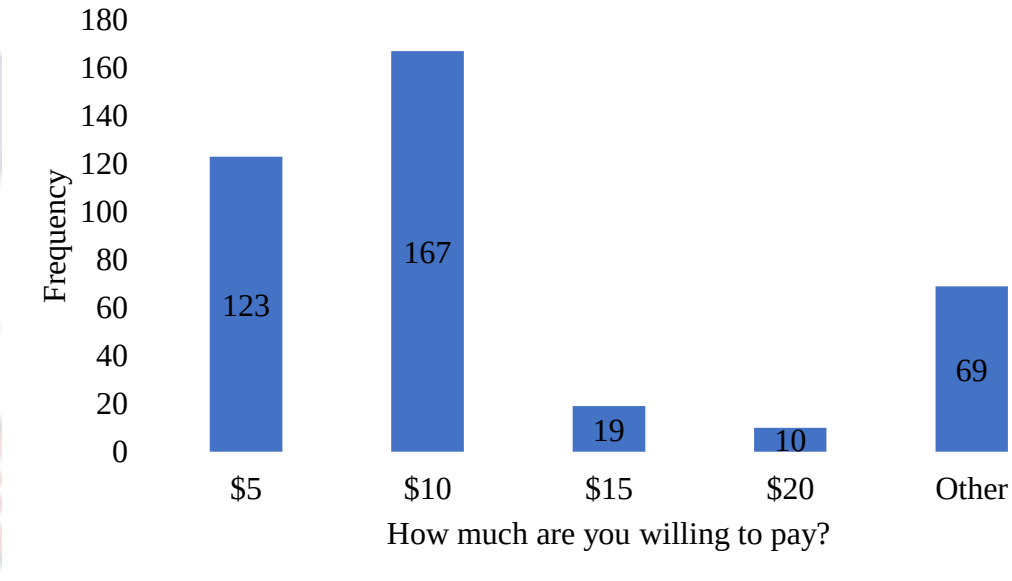

Figure 20: Amount respondents are willing to pay (in dollars).

Fewer respondents, 19 (or 4.9%) and 10 (or 2.6%), showed a willingness to contribute $15 and $20 respectively. Interestingly, 69 respondents (or 17.8%) specified amounts other (any amount) than the given options.

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Expectations from payment for solid waste collection

As shown in figure 21, a significant of 374 out of 388 respondents (or 96.4%) expressed expectations related to "Waste Management. In contrast, only 10 respondents (or 2.6%) specifically mentioned the "Buchanan City Corporation" (BCC), and a minimal of 4 respondents (or 1%) highlighted "Regular waste collection" as their primary expectation.

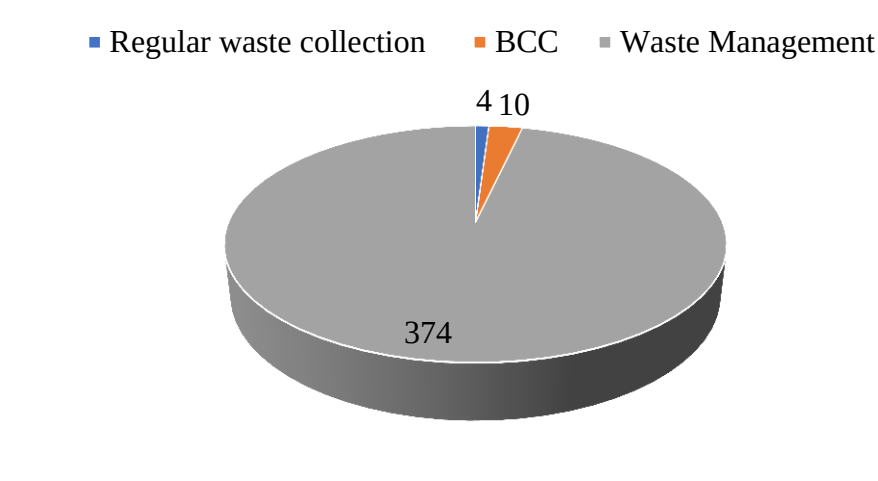

Figure 21: Expectations from payment for solid waste collection

Frequency of payment

As illustrated in figure 22, a majority of 251 out of 388 respondents (or 64.7%) favoured a weekly payment system, comprising 118 respondents (or 30.4%) opted for a monthly payment plan and, a smaller proportion, 19 respondents (or 4.9%) expressed a willingness to pay daily.

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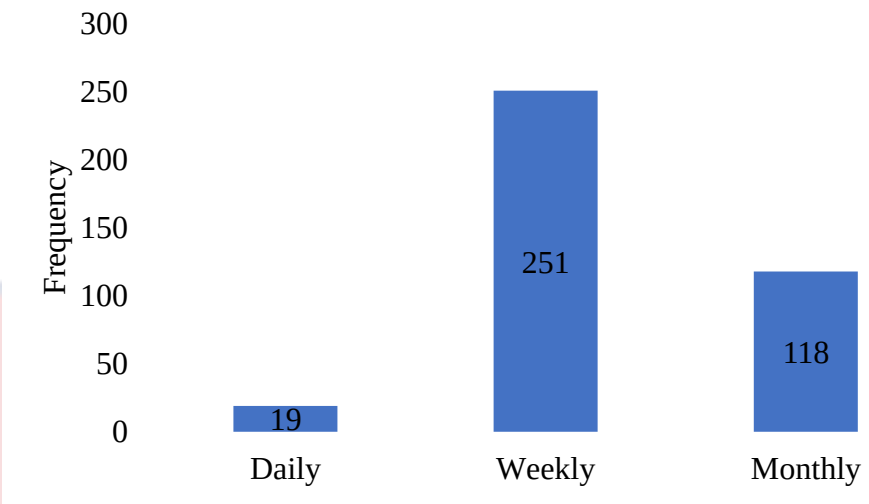

Figure 22: Frequency for payment

Frequency for solid waste collection

As illustrated in figure 23, a substantial majority, with 332 respondents (85.6%) of 388 respondents, expressed a desire for weekly waste collection Meanwhile, 46 respondents (11.9%) opted for a twice-a-week collection and a smaller group, comprising 10 respondents (2.6%), favoured daily waste collection,

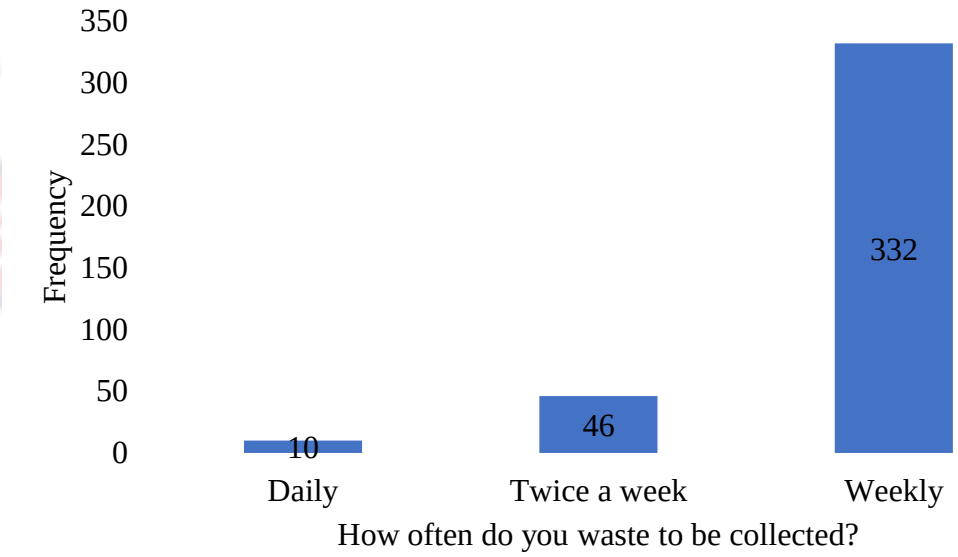

Figure 23: Frequency of solid waste collection

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CHAPTER FIVE

DISCUSSION

The essence of this study was to estimate the quantity and physical composition of the domestic solid waste generated in Buchanan City, Grand Bassa County, Liberia. Also, this study delves into the dynamics of household solid waste generation and the existing waste management practices within Buchanan City, Liberia. The preceding chapters have established the groundwork, detailed the research methodology and provided a comprehensive review of relevant literature.

Physical Composition of Domestic Solid Waste in Buchanan City

The substantial presence of organics in the studied location in Liberia can be attributed to the country's pronounced reliance on agricultural products and dietary patterns (FAO, 2023). This dependence on agriculture translates to a significant portion of the population engaged in farming and related activities, leading to more organic waste generation, including agricultural remnants, food waste, and other biodegradable materials. As implemented in the studied location, this comprehensive breakdown of the major waste components into eight distinct categories has enabled pinpointing of specific waste fractions that hold significant potential for energy recovery and recycling endeavors (Davies et al., 2019; EPA Liberia, 2019).

The observed trend in the physical composition of domestic solid waste in this study mirrors the composition of household waste in many developing Countries. In such regions, a substantial amount of organic waste fractions is generated from the preparation of unprocessed food. In contrast, developed countries depend more on processed and ready-to-eat foods, leading

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to a lower proportion of organic waste but a higher proportion of packaging materials. It is important to note that various studies, including those by Gomez et al. (2009), Seshie et al. (2020), and Agyei (2020), have underscored the noteworthy role of food and garden waste in the overall organic waste streams of numerous developing nations, accounting for approximately 65.1%. The study's findings, which show that the organic waste fraction averages at 19.7%, constituting the largest portion of generated waste, are consistent with previous research conducted in Ghana by Miezah et al. (2015) and Seshie et al. (2020). Some patterns have also observed in other Sub-Saharan African countries, such as Ibadan (56.0 % organic waste in household solid waste), Kampala (75.0 %) in Uganda and Accra (85.0 %) in Ghana.

The largest proportion of organic waste was evident in Barcorline community. This trend could be attributed to the fact that more high-income household disposed leftover food and other organics in the waste bins. Moreover, leftover food from these establishments often finds its way into household bins, contributing to the higher organic waste fraction observed.

Conversely, the low-income area displayed the lowest fraction of organic waste. This disparity is primarily because a substantial portion of organic waste in this area is repurposed as animal feed, reducing the amount of organic waste disposed of as household waste. Also, the cascading of food is common in this area therefore, limited portion of the organic waste goes to the household waste bins. This finding aligned with similar study by Oteng-Ababio (2014) in Takoradi, Ghana.

In the middle-income area, organic waste ranked as the third highest fraction of waste generated at 14.8%. Notably, this category included a

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significant presence of peels from indigenous food products like cassava, eddoes, banana, and plantain. This phenomenon can be attributed to the culinary practices within these communities, where staples such as gari, plantain chips, and fufu are commonly prepared, leading to the accumulation of peels as organic waste with 59.6 %. This study aligns with the findings reported by Addae et al. (2021) regarding the energy potential of MSW in Kumasi, Ghana.

Additionally, in the high-income area, a significant portion of the organic waste fraction resulted from yard trimmings. This observation is associated with the existence of well-maintained lawns and gardens within the residents' premises, a feature that is more prevalent in higher-income areas. Following organic waste (19.7 %), textiles waste (15.3 %) emerged as the next prominent fraction, mainly comprised of used clothing, imported and sold to the populace. Plastic was the third prominent fraction constituting (14.3%), this waste might be generated from low-density polyethylene (LDPE) and high-density polyethylene (HDPE) materials, particularly pure water sachets. The highest plastic waste generation was documented in the middle-income area at (20.4%), while the lowest was observed in the high-income area, accounting for only (5.8%). This observation in this study agreed with similar studies by Wright et al. (2022) and Rolewicz-Kalińska et al., (2020).

Paper waste mainly consisted of materials such as cardboard, newsprint, tissues, and diapers across all socio-economic regions. In contrast to more developed cities and countries, the presence of paper waste in the study areas of Buchanan City, Grand Bassa County, was relatively lower. This disparity underscores how the higher proportion of packaging waste generated

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by the affluent population is shaped by their increased financial resources and greater capacity for consumption. Studies conducted by Oyelola and Babatunde (2008) and Wright et al. (2022) have identified a clear correlation between the components of packaging waste within household waste and the household income level. Affluent households tend to generate significantly higher proportions of organic, paper, and metal waste for packaging purposes. The composition of packaging materials observed in the high-income areas of this study conforms to this trend. In contrast, the low-income area exhibited the lowest production of packaging waste.

The middle-income area stood out with the highest percentage of plastic waste (20.4 %), whereas the fractions of plastic waste in the low income and high-income areas were (16.6 %) and (5.8 %), respectively. The reduced proportion of plastic waste in the high-income area might be attributed to the practice of buying items in bulk, also paper packing is mostly used as an alternative for plastics, thereby decreasing the number of discarded plastics.

The average PCWGR of 0.512 kg/capita/day from this study falls slightly below the per capita generation rate of 0.72 kg/capita/day reported by Miezah et al. (2015) for most major metropolitan cities in Ghana, excluding Tamale. However, it slightly surpasses the estimated average waste per capita generation rate of 0.5 kg/capita/day documented by Ezeudu et al. (2019) in Nigeria. Moreover, this outcome aligns with the global trend of waste generation rates in developing countries, which typically range from 0.5 kg/capita/day to 0.9 kg/capita/day, as highlighted by Gomez et al. (2009). The PCWGR in Liberia, regardless of socioeconomic factors varied between 0.2

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and 0.9 kg/person/day. This range is also observed in most cities across Sub-Saharan Africa, as noted in studies conducted by Friedrich and Trois (2011) and the United Nations Environment Programme (UNEP, 2013).

Comparison of Material Composition between Low- and Middle-Income Groups

In ascertaining the variation showed statistically significant difference in the waste fractions generated across the low- and middle-income groups. This variations may be associated with the consumption pattern, and perhaps as a result of the urbanization process in the city's context-specific traits (Lozano Lazo et al., 2023). The composition of generated waste can vary significantly due to seasonal, geographic, and social factors (Dikole & Letshwenyo, 2020; Noufal et al., 2020; Tiew et al., 2010).

Comparison of Material Composition between Low- and High-Income Groups

In ascertaining variation showed statistically significant difference in the waste fractions generated across the low- and high-income groups. This variations may be associated with the consumption pattern, and perhaps as a result of the urbanization process in the city's context-specific traits (Lozano Lazo et al., 2023). Due to seasonal, geographic, and social factors, the composition of generated waste can vary significantly (Dikole & Letshwenyo, 2020; Noufal et al., 2020; Tiew et al., 2010)

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Comparison of Material Composition between Middle- and High-Income Groups

In ascertaining the showed statistically significant difference in the waste fractions generated. Conversely, only inert (F (1, 14) = 2.54; p = 0.13), had no variation in the material composition; hence showing no statistically significant difference between the middle- and high-income groups. This variations may be associated with the consumption pattern, and perhaps as a result of the urbanization process in the city's context-specific traits (Lozano Lazo et al., 2023). Due to seasonal, geographic, and social factors, the composition of generated waste can vary significantly (Dikole & Letshwenyo, 2020; Noufal et al., 2020; Tiew et al., 2010).

Material Composition Across Income Groups for Waste Fractions

To establish the relationship (significant difference) exiting between material composition, for the fractions of waste generated across the three income levels (high, middle, and low), analysis of variance (one-way Anova single factor) was performed on the means of the various waste material. The result established that no statistically significant differences (p= 0.08) were observed in the weights of inert waste across the three income levels. All other waste fractions (organic, paper, plastic, metal, rubber, textiles and miscellaneous) exhibited statistically significant differences (p = 0.00) across all three income levels.

Per capita waste generation rate in Buchanan City

Greater levels of urbanization, per capita trash production, and per capita residential waste creation are associated with bigger municipal populations (Pathak et al., 2020; Rodzi et al., 2019). According to the study's

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findings, the high-income group generated solid waste at a rate of 0.84 kilograms per person per day (54.6%), middle-income group generated 0.036 kilograms per person per day (23.3%), low-income group produced 0.34 kilograms per person per day solid waste (22.0%), with an average of 0.51 kilograms per person per day (33.3%). Overall high-income generated largest quantity of waste, followed by middle- and low income respectively.

Crucially, when assessed at a significance level of 5%, there were statistically significant differences ($p = 0.00$) observed in the PCWGR, among the three-income high, middle, and low areas. This finding underscores a relative uniformity in waste generation patterns across these levels.

Per Capita Waste Generation at different Income Levels

To validate the statistically significant difference in PCWGR among the three income levels (high, middle, and low), a post-hoc test was performed following a one-way analysis of variance (ANOVA) on a dataset collected from Buchanan City, Liberia. A Tukey's Post Hock test (Nell et al., 2022) was performed as the confirmatory test.

It is evident that in week 1- 5, statistically there is no significant difference in PCWGR between the middle- and low-income levels, conversely, there is a distinction between the high-income level group when compared with both the middle- and low-income level groups. The same cannot be established for the rest of the weeks (weeks 6-8), In weeks 6-8, there is a statistically significant difference between the PCWGR at high-, middle- and low-income groups. Overall, the high-income group generated the largest total quantity of waste (4559.89 kg/capita) followed by the low-income group

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(3224.93 kg/capita), with middle income group (3113.83 kg/capita) generating the smallest amount of waste.

The PCWGR might be attributed to the consumption pattern and lifestyle of the populace residing in respective income level group. The dynamics in the total PCWGR , might be linked to the affluent lifestyle of more purchasing items in the high-income group, and donation of items that are not useful anymore in the high-income group, mostly to the less privileged causing more garbage in the low-income group compared to the middle-income level.

Relationship between domestic solid waste generation rate and income level

The interplay between PCWGR and household income level was also highlighted in this study. While prior research, such as that conducted by Qdais et al. (1997), established a positive relationship between waste generation and higher income levels, this present study observed a similar correlation between household income and waste generation. Notably, the findings of this study harmonize with research was undertaken in Ghana by Miezah et al. (2015), in Mexico by Gomez et al. (2008), and in Gaborone, Botswana by Bolaane and Ali (2004).

It is crucial to emphasize the lack of a direct link among household income and waste generation in this study may be attributed to various factors such as; particularly, the possibility of affluent individuals residing in areas classified as lower socio-economic zones might contribute to this observed lack of correlation. This, in conjunction with other influential factors, could

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collectively contribute to the nuanced waste generation patterns observed in this investigation.

Furthermore, this study revealed an intriguing pattern: individuals living in larger households tended to produce less waste compared to those in smaller households. This trend can be attributed to the practice of larger households making bulk purchases or obtaining larger-sized packages, which are then shared among all household members. As a result, the overall waste generated is constrained in comparison to scenarios where everyone opts for smaller packages. A study by Grover and Singh (2014) conducted in India echoed similar findings, further corroborating this observed phenomenon.

Demographic Information of Respondents

The religious landscape, as reflected in the study, is predominantly Christian, with 84% of respondents identifying with this faith. Islam, followed by 11%, and traditional practices, adhered to by 5%, might also have unique waste generation patterns, especially during religious events. Residential data shows a trend of high mobility, with 40% having resided in their current community for just 0-4 years. This transient nature could affect residents' commitment to long-term waste management initiatives. Households, especially those with 4-6 and 10 or more individuals, might produce more waste given their size. This gender distribution might influence household roles and responsibilities, including municipal solid waste management. The age factor offered additional insights; 55% of respondents fall within the 18-27 age bracket, followed by 20% in the 28-37 age range. This younger demographic, especially those who might be living independently or starting

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young families, could potentially be generating distinct patterns of domestic waste, influenced by their consumption habits.

The educational background of the participants offers promising prospects for waste management awareness campaigns. A significant 71% have university-level education, potentially making them more receptive to structured waste management practices and the importance of sustainability. The diverse occupational status, with 36% being self-employed and 30% unemployed, suggests varying daily routines and, consequently, different waste generation habits. Those in formal employment, making up 18%, might have structured waste disposal practices influenced by their workplace policies. Meanwhile, traders, farmers, and students could offer unique insights into sector-specific waste generation and disposal habits.

Economic considerations play a pivotal role in waste generation and disposal practices. With 51% of the sample earning between $50-150, the choice of products consumed, and consequently the type and amount of waste generated, is influenced by budget constraints. Recyclable products or sustainable choices might be out of reach for this segment due to cost considerations. The non-disclosure of income by 26% suggests a segment of the population that might be hesitant to partake openly in studies or community initiatives, including those related to waste management. The variety in income levels, from as low as $50 to as high as $750, indicates a diverse range of consumption patterns, each with its waste generation implications.

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Willingness to Pay for Solid Waste Management Services by Predictors

In linear regression, the adjusted R-square demonstrates the generalization of the results, or the variation of the sample results from the population. A minimal difference between R-square and Adjusted R-square must exist. In this research (R^2 = 0.012), which is close to (Adjusted R^2 = 0.010) making it acceptable which is consistent with study by Jain (2019).

The significance value is the only value that matters for interpretation. For the 95 percent confidence interval in this study, the value should be lower than the accepted threshold of significance. If $p < 0.05$, the null hypothesis is rejected based on the significance level. This implies, there is an impact by the predictor on the dependent variable.

When $p > 0.05$, the null hypothesis is accepted. Thus, no impact exists between the predictor and dependent variable, hence the dependent variable is not influenced by the predictor (Jain, 2019).

The gender significantly influences the willingness to pay for solid waste management services. This is because the sig. value, ($p = 0.014 < \alpha = 0.05$) which is lower than the permitted limit of 0.05. Also, willingness to pay for solid waste management services will increase by 0.092 percent (B= 0.092) for every 1.4 percent of gender (Anjum, 2013).

Solid Wastes Management Practices Among Residents in Buchanan

The second objective of the study pursued to determine solid waste management practices among residents of Buchanan. Structured questionnaires on solid waste management practices were administered to participants. The data gathered was analysed and findings were presented systematically as follows:

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Disposal of Waste

The current waste disposal landscape in Buchanan City underscores a pressing need for public awareness campaigns, infrastructure enhancement, and the promotion of sustainable disposal methods to foster a more environmentally responsible waste management approach.

The prevalence of burning as a primary waste disposal method, adopted by 55.8% of the respondents, echoes the results of Ike et al., (2018) who noted that in many West African cities, burning is a common practice due to the absence of formal waste management systems and limited public awareness of its environmental consequences. These airborne emissions from burning contribute significantly to air pollution, a sentiment that aligns with deSouza (2020), who observed that such practices in Kenya have led to deteriorating air quality over the past decade. The open dumping observed by 43.2% of the residents is consistent with findings from Maturi et al., (2022), who documented that over 40% of urban residents in sub-Saharan Africa resort to open dumping, primarily due to inadequate waste collection services and lack of accessible disposal facilities. This method's environmental and health hazards, such as groundwater contamination and disease proliferation, have been extensively documented by Maturi et al., (2022). Findings from this study revealed that only 0.6% of respondents practice composting, which is in contrast with urban trends in Northern Africa, where composting is gaining traction due to public awareness campaigns and government incentives (Adeleke et al., 2021). The minuscule percentage of residents in Buchanan City who burn and bury their waste, while not extensively covered in

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literature, suggests a localized practice that might be unique to specific regions or communities.

Designated area for solid waste disposal

Most of the respondents in addition stated that they have designated locations for waste disposal. Of the respondents surveyed, 51.6% confirmed having designated areas for waste disposal, while 48.4% indicated the absence of such areas. This near-equal distribution indicates a significant disparity in waste management practices within the city. The presence of designated disposal areas, as found by Sotamenou et al., (2019), often correlates with organized waste management, reduced open dumping, and more environmentally friendly disposal methods. In contrast, the lack of such areas can lead to adverse practices like open dumping or burning, a trend also observed by Sotamenou et al., (2019) in Yaoundé (Cameroon). Ingwani et al. also documented that urban residents in regions with inconsistent municipal services often resort to makeshift waste disposal methods due to the lack of designated areas Ingwani et al. (2023).

Waste Collection System

The overwhelming preference for old buckets, as observed in 62.4% of respondents, suggesting a prevalent reuse culture or potentially limited access to specialized waste storage equipment., echoes the findings of Salim et al.,(2023) who identified a prevalent culture of repurposing containers in urban West African settings. Such practices, as they argued, often arise from a combination of economic constraints and limited access to specialized waste storage solutions (Salim et al., 2023). The equal preference for individual plastic containers and old drums, each at 8.8%, finds parallels in the work of

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Suryawan et al., (2023), who highlighted the adaptability of urban residents in repurposing available containers or waste in Jakarta, Indonesia. Interestingly, the use of rice bags, though minimal in our study at 1%, was documented by Lucien as a localized practice in some East African urban settings, pointing towards the resourcefulness of residents in the absence of traditional waste storage solutions (Lucien et al., 2022). The varied storage methods reflect a blend of resourcefulness, economic considerations, and accessibility to proper waste storage solutions in the community.

Presence of a waste collection system

The presence or absence of a collection system after temporary waste storage is pivotal in determining the efficiency of waste management in an municipal setting. The majority suggests potential gaps in the city's waste collection infrastructure, possibly leading residents to resort to less sustainable disposal methods, such as open dumping or burning.

Among the respondents who confirmed the presence of a collection system from their yards, there is a variation in the entities responsible for this service.

Institutions responsible for solid waste collection

The institutions responsible for solid waste collection, therefore it suggests a significant municipal involvement in waste collection services indicating a substantial role of the private sector in bridging the waste collection gap. This low figure might imply that the EPA's role in the city is more regulatory and supervisory than operational in terms of direct waste collection.

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Frequency of private waste collection services

This suggests that a structured, regular collection system is in place for many households with a less frequent but still consistent service. The varied frequencies reflect the diverse needs of households and the adaptability of private service providers in meeting these demands. Interestingly, the distinction in this context remains unclear.

Rating of private solid waste collection services

Assessing the performance of private waste collection service providers, respondents offered varied ratings, indicating high satisfaction and reliability associated with private entities and suggesting the service meets basic expectations, there may be areas for improvement.

Concerningly, the near-even spread across these ratings underscores the variability in service quality and user satisfaction within the private waste collection sector.

Use of waste for Fertilizer and Energy Production

As highlighted in the results, this consensus indicates a strong community inclination towards sustainable waste management practices and the potential for circular economy initiatives. The data suggests that residents recognize the value of organic waste repurposing and are open to practices that benefit the environment and potentially support local agriculture. Such a unanimous response underscores the opportunity for implementing waste-to-resource programs, especially those centred around composting and organic fertilizer production, within the community.

Despite the unanimous willingness of the surveyed population to use food and vegetable wastes for fertilizer production, there's a stark contrast

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when it comes to knowledge on the actual process. All 500 respondents (100%) admitted to having no knowledge of how to turn waste into fertilizer. This highlights a significant knowledge gap in the community regarding sustainable waste management practices. While there's evident enthusiasm for environmentally friendly initiatives, the lack of know-how could be a potential barrier to actual implementation. This underscores the urgent need for awareness campaigns, educational programs, and hands-on training to equip residents with the skills and knowledge required to transform their organic waste into valuable resources like fertilizer.

Availability of infrastructure for solid waste disposal

It was reported that the absence of public bins or communal areas for waste disposal in or near their community suggests a potential deficiency in communal waste management infrastructure, which could lead residents to adopt less sustainable disposal methods. It was confirmed that the presence of such facilities, indicating that only a fraction of the community has easy access to structured waste disposal points. The disparity shown in the results in these figures emphasizes the need to bolster communal waste disposal infrastructure, ensuring that residents have convenient and environmentally sound options for their waste.

Frequency of emptying bins

Regarding the frequency of emptying public or communal bins, the responses depicted varied waste management practices. This suggests a structured, albeit potentially insufficient, waste collection routine for some areas, indicating a slightly more frequent service for certain localities highlighting potential irregularities in service or a lack of community

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awareness regarding waste collection schedules. The range in responses underscores the variability in service quality and frequency across different communal disposal.

Size of solid waste bins

Examining the adequacy of public or communal bins in terms of size and it suggests that potential challenges related to overflow, which can lead to unsanitary conditions, attract pests, and contribute to environmental degradation. The disparity in these figures underscores an infrastructural concern, emphasizing the need to revisit and potentially upscale the waste storage solutions in communal areas to better cater to the community's needs.

Waste Management Strategies

It sought to assess the existing institutional framework for MSWM in Buchanan City, Liberia. The results reveal a pronounced individualistic approach to waste management indicating that individuals are predominantly responsible for their own waste. This suggests that many residents adopt a self-reliant strategy, possibly driven by a lack of centralized waste collection services or community-wide initiatives, while individual responsibility can empower residents to manage their waste. It might also lead to inconsistent disposal practices, depending on each person's knowledge, resources, and awareness. This indicates a municipal effort to streamline waste management, potentially offering more structured and organized waste disposal services to a segment of the population.

Community-led waste management efforts, though not as prevalent as individual or municipal actions, are still noteworthy. Such grassroots efforts can be instrumental in fostering sustainable practices and promoting

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community cohesion. Surprisingly, the private sector's role seems almost negligible in this landscape identifying a private entity as overseeing waste. This could point to the limited commercialization of waste management services or perhaps reflect the dominant roles of individual, community, and municipal entities in this arena.

The pronounced individualistic approach to waste management, as observed with 71.2% of respondents managing their waste, mirrors the findings of Owojori et al. (2022), who documented a similar trend in several South African urban settings. Such a self-reliant strategy, as posited by Compagnoni et al. (2022), can often arise due to gaps in formal waste collection services, pushing residents to develop their own disposal methods. While individual efforts can be empowering, inconsistencies in disposal practices become inevitable, a concern highlighted by Compagnoni, M. (2022). Meanwhile, the role of Corporations in waste management, identified by 18.4% of respondents, resonates with the observations of Owojori et al., (2022). They noted the increasing involvement of municipal bodies in sub-Saharan African cities, aiming to provide structured waste management services.

Owojori et al., (2022) also highlighted the value of grassroots initiatives in fostering communal cohesion and sustainable waste management practices in urban Africa. Such community-driven solutions, as argued by Oja Da Silva (2023), can often fill the void left by inadequate municipal services, serving as a bridge until more formal systems are established. On the other hand, the negligible role of the private sector in this context, contrasts sharply with the trends observed in cities like Nairobi and Johannesburg, where

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private waste management enterprises have gained prominence (Mlambo et al., (2023). This discrepancy might hint at unique challenges or opportunities within the waste management landscape of Buchanan City, Liberia.

Awareness of waste management strategies

The survey results shed light on the level of awareness regarding waste management strategies among residents. This suggests a relatively informed population, likely reflecting the impact of previous awareness campaigns, educational programmes, or perhaps the intrinsic motivation of residents to understand waste management due to environmental or health.

The overarching positive trend towards awareness is encouraging, yet it emphasizes the ongoing need to bridge knowledge gaps and ensure that the entire community is informed about sustainable waste management practices.

Solid waste management strategies

The data provides insight into the waste management strategies actively promoted by residents. This high reliance on dumpsites might suggest a traditional approach to waste management or possibly the economic constraints that hinder the adoption of more advanced methods. However, dumpsites can pose environmental and health risks, such as groundwater contamination, disease vector proliferation, and atmospheric pollution. On the other end of the promotion of the "Waste to Energy" method, this modern strategy, while environmentally efficient, often requires substantial investment and technological expertise. Other methods that the residents promote fall between the traditional and modern extremes. Incineration, while effective in volume reduction, raises concerns about air pollution and the release of harmful toxins. Burying is a step above open dumping, but the practice can

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lead to soil contamination if not managed properly. Composting is an eco-friendly method of converting organic waste into nutrient-rich material. Though it's environmentally beneficial, the relatively low frequency suggests limited awareness or infrastructure to support large-scale composting within the county.

Common solid waste management strategies

In evaluating the prevalent waste management strategies within the community, the data reveals a clear inclination towards more traditional methods. Dumpsites, emerge as the most common strategy. Their dominance could reflect ease of implementation, especially in contexts where advanced waste management infrastructure might be lacking or financially prohibitive. However, the extensive use of dumpsites can lead to environmental concerns, such as leaching pollutants and breeding grounds for disease vectors. Burning and burying are also notably common identifying these methods respectively. Both these practices, while rudimentary, are often adopted for their immediacy and simplicity. Yet, they pose environmental challenges, with burning leading to air pollution and burying potentially causing soil contamination.

Contrasting with traditional methods, modern waste management strategies appear to be less prevalent. Incineration is a method that can efficiently reduce waste volume but might raise concerns regarding air quality and toxin release. Composting, an environmentally friendly approach to repurposing organic waste, suggested that there was limited awareness or infrastructure support within the community. Additionally, 2 respondents (or 0.4%) identified other waste management strategies not listed in the survey, hinting at niche or novel approaches adopted by a fraction of the community.

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The data underscores the community's reliance on traditional waste management methods, with limited adoption of more modern, sustainable strategies.

Challenges in solid waste management

The surveyed population highlighted several challenges they face regarding solid waste management. It was identified that the inadequacy of waste bins was a primary concern, suggesting an overwhelming need for larger or more numerous bins to cater to waste generation rates, and it pointed out the infrequency of waste collection as a challenge, indicating potential gaps or irregularities in waste collection schedules.

A lack of waste bins altogether was reported, emphasizing a foundational infrastructure concern. Interestingly, only a small fraction cited expensive waste collection bills as a challenge, suggesting that financial concerns, in this context, are secondary to infrastructural and service-related issues. The prominent challenge of inadequate waste bins, identified by a significant 85.2% of respondents, resonates with observations made by Owojori et al., (2022). They highlighted that in many urban African settings, the rapid pace of urbanization often outstrips the provision of adequate waste management infrastructure. Owojori et al. (2022) argued that inconsistent waste collection services, often resulting from logistical or financial constraints, can exacerbate waste accumulation and related environmental issues. Adinarayanappa, et al. (2022) found that certain urban pockets, especially in rapidly developing regions, often lack basic waste management amenities Adinarayanappa et al. (2022). Surprisingly, the minimal concern over expensive waste collection bills, cited by a mere 0.8% of respondents, contrasts with Ke et al., (2022)

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study, they observed that in various urban contexts, the financial burden of waste management services remains a primary deterrent for residents.

Willingness to Pay for improved wastes management services

In Buchanan City, effective solid waste management stands as a pivotal concern for urban sustainability. This provides an insight into residents' financial commitment to improved solid waste services, revealing the community's readiness and potential barriers to enhanced waste management solutions.

The survey results indicate a significant disparity in the system of paying for waste collection within the community. A vast majority reported the absence of a payment system for waste collection. This suggests that structured financial mechanisms or formalized waste collection services might be lacking, potentially leading residents to manage their waste independently or rely on informal methods., hinting at some level of organized waste collection services available to a fraction of the community. The pronounced difference emphasizes the potential challenges and inconsistencies in waste management due to the absence of a standardized payment.

Frequency of payments made to the service providers

The frequency of payments made to waste collection service providers in Buchanan City. When respondents were asked about the recipients of payments for waste collection services in the community, their answers indicated a combination of formal and informal entities. The Buchanan City Corporation (BCC), presumably a formal municipal authority, was identified as the primary entity that pay for waste services. This indicates a structured waste collection system supported by municipal oversight for a segment of the

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population. However, "street boys" were reported to be paid, suggesting the presence of informal waste collection agents operating within the community. This could reflect gaps in official services or an alternative, community-driven approach to waste collection. Interestingly, the "Community Head" played a minimal role for local community leaders in direct waste management financial transactions.

The willingness of indigenes of Buchanan to pay for solid waste collection service

The survey results indicate a notable inclination among the community members towards financially supporting waste collection services and expressed their willingness to pay for waste collection, highlighting a community that recognizes the importance of organized and efficient waste management. This willingness could stem from an understanding of the environmental and health benefits associated with structured waste collection. However, with the suggesting potential financial constraints, scepticism about the efficiency of services, or perhaps satisfaction with their current waste management practices. The data underscores a predominantly positive disposition towards contributing to waste management but also emphasizes the need to address the concerns or limitations of the dissenting.

Amount respondents are willing to pay

When assessing the amount residents are prepared to pay for waste collection services, the results showed a range of financial commitments. It was suggested that the said amount was perceived as reasonable or manageable for many hinting at budgetary constraints or a valuation of the services at this rate.

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Fewer respondents, indicating a smaller segment of the population is ready to invest more in waste management services. Interestingly, specified amounts other than the given options, reflecting diverse financial capabilities or unique valuations of waste collection services within the community.

Expectations from payment for solid waste collection

Regarding participants' expectations in return for their payments for waste services, a significant expressed an expectation related to "Waste Management," which likely encompasses comprehensive services like timely collection, proper disposal, and recycling initiatives.

The community overwhelmingly prefers organized and effective waste management procedures in return for their monetary contributions. On the other hand, the "Buchanan City Corporation" (BCC) seems to suggest an anticipation of more extensive local participation or supervision in waste disposal. Only a small number of respondents prioritized "Regular waste collection," indicating that timely and consistent pick-up is the primary concern for this group.

Frequency of payment

Concerning the preferred frequency for making payments towards waste collection services, respondents exhibited clear preferences suggesting a comfort with regular, short-term financial commitments.

This could also reflect the desire for frequent waste collection services in line with their payment schedule. The next significant group, opted for a monthly payment plan, hinting at a segment of the population that prefers consolidating their expenses over a longer duration. A smaller proportion, expressed a willingness to pay daily, which might indicate a preference for

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day-to-day waste collection services or the financial ease of smaller, daily payments.

Frequency of solid waste collection

When assessing the preferred frequency for waste collection, a significant majority of respondents expressed a preference for weekly waste collection. This preference highlights the community's aspiration for a consistent yet not overly frequent waste management routine, potentially balancing convenience with the practicalities of waste accumulation. Meanwhile respondents opted for a twice-a-week collection, indicating a segment of the population that might generate waste at a quicker rate or prefers a more frequent collection schedule. A smaller group, comprising respondents favoured daily waste collection, reflecting specific needs for immediate waste removal or perhaps households with higher waste generation. The data emphasizes the community's predominant inclination towards weekly waste collection services.

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CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This chapter recapped the main findings, drew a definitive conclusion, and recommendations for actionable steps toward improvement. The chapter also provided suggestions for future research.

Conclusion

The study on solid waste quantification, characterization, and management practices in Buchanan City provided accurate data on the Physical Composition and quantity of domestic Solid waste generated and the PCWGR at three socioeconomic levels in Buchanan City and the mean waste generated for the physical composition and domestic solid waste was in the order of 2342.4kg>1957.3kg>1865.5kg for the middle-income area, the high-income, and the low-income area respectively. The high-income area recorded the highest per capita waste generation rate (PCWGR) of 0.84 kg/capita/day whilst the lowest of 0.34 kg/capita/day was recorded within the low-income area. On average, the organic waste fraction recorded the highest of 19.7%kg across the three income levels also, an assessment on the community's proactive attitude towards achieving a cleaner and more sustainable environment.

The study shows that awareness for solid waste management practices among some selected residents in Buchanan, Liberia was low. Keen interest in evaluating the SWM practices adopted environmentally friendly waste disposal practices, underscores a community ready for transformative change. The younger demographic profile of the city further suggests adaptability and

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openness to new, innovative waste management strategies, positioning Buchanan City at the forefront of sustainable urban development.

In assessing the existing institutional framework for municipal solid waste management in Buchanan City, Liberia, there are areas for improving the existing framework which provides a foundation upon which more advanced and sustainable waste management practices can be built. The challenges identified from infrastructural gaps to service regularity, can be viewed as opportunities for enhancement. Given the community's cooperative spirit and the evident institutional framework, there's significant potential for Buchanan City to evolve into a model for efficient and sustainable waste management, benefiting both its residents and the environment.

The prevalent willingness among residents to contribute financially for an improved waste management services in Buchanan City, Liberia and the notable willingness of most residents to financially contribute to improved waste collection services signifies more than just an acknowledgement of the service's value. This preference indicates a more profound understanding and acknowledgment of the broader environmental, health, and societal consequences associated with efficient waste management. Such a sentiment, especially when prevalent in a significant portion of the community, becomes a foundation upon which transformative waste management initiatives can be built.

Recommendations

Based on the findings of the study's, the following recommendations were put forth:

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Strengthening Public Education and Awareness Programmes: The study indicated a gap in knowledge regarding certain sustainable waste management practices, such as turning waste into fertilizer. Comprehensive public education and awareness campaigns should be introduced, emphasizing the environmental, health, and societal benefits of proper waste management. These campaigns can leverage local media, community workshops, and school programmes to reach a broad audience.

Infrastructure Development and Upcycling:

The prevalent issue of inadequate waste bins and infrequent waste collection highlights a pressing need for infrastructural development. Investments should be made in acquiring more waste bins, ensuring they are strategically placed, and establishing a regular and efficient waste collection system. Additionally, the establishment of modern waste treatment facilities, such as recycling centres and waste-to-energy plants, can further enhance waste management.

Introduce Incentive-Based Waste Management Systems: Given the community's willingness to pay for waste management services, an incentive-based system could be introduced. Residents who adopt sustainable waste disposal practices, like composting or recycling, could receive discounts or rewards. Conversely, a "Pay-as-You-Throw" system can be implemented, charging residents based on the amount of non-recyclable waste they produce, thus encouraging waste reduction at the source.

Collaboration with Private Entities and Community Participation: Engage with private entities to enhance waste management services. Private collectors and companies can bring in expertise, technology, and innovative solutions. Moreover, foster community participation in waste management

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decision-making processes. Establishing community waste management committees can ensure that strategies and implementations align with local needs and values, ensuring a more effective and community-centric approach.

Suggestions for Future Research

Given the insights obtained from this study on solid waste management, it would be beneficial for future research to delve deeper into the behavioural aspects of waste management among residents. Specifically, understanding the underlying motivations, barriers, and cultural or socio-economic factors that influence residents' waste management practices can offer a more holistic perspective. Such a study could employ qualitative methods like in-depth interviews, focus group discussions, and ethnographic observations to capture the beliefs, attitudes, and practices related to waste management.

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APPENDIX B: Data collection form for per capita waste generation rate

Household Code	Household size	Week 1							
		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Total (Kg)
R001									
R002									
R003									
-									
-									
--									
-									
--									
-									
-									
-									
-									
-									
-									
-									
-									
-									
-									
-									
B032									
Total									

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APPENDIX C: Data Collection Form for Domestic Solid Waste Material Composition

Physical Composition of Domestic Solid Waste								
	Week 1							
Components	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Total**
Organics								
Paper								
Plastics								
Metals								
Inert materials								
Textiles								
Rubber								
Miscellaneous								
Total								

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APPENDIX E: Data collection instrument

Quantification, characterization, and management practices of Municipal solid waste in Buchanan City, Liberia

My name is Ama Mardea Awotwe. Im an MPhil (Environmental Science) from the University of Cape Coast Ghana. As a requirement of the program, I am conducting research on "**Quantification, Characterization, and Management Practices of Municipal Solid Waste in Buchanan, Grand Bassa County, Liberia**" The objective of this study is to gather information on the quantification, characterization, and management practices of municipal solid waste of the selected households in Buchanan, Liberia which could be used to achieve the research objectives and data inputs in developing plans and policies for solid waste collection, recycling, and disposal.

Therefore, I am asking for you to grant me time so that I can complete this questionnaire. Your information will be kept private and confidential and used solely for research and academic purposes; therefore, this will not be used anywhere else. Thank you in advance for your assistance.

Ama Mardea Awotwe

Contacts details: +233594808446/231777122827

Email: queenama1111gmail.com & ama.awotwe@stu.ucc.edu.gh

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Section I. Demographic Characteristics

1. **Gender:** Male: [ ]
   Female [ ]

2. **Marital status:**
   Single [ ]
   Married [ ]
   Divorced [ ]
   Separated [ ]
   Widowed [ ]

3. **Age range:** 18-27 [ ]
   28-37 [ ]
   38-47 [ ]
   48-57 [ ]
   58 and above [ ]

4. **Religion**: Christianity [ ]
   Islam [ ]
   Traditional practice [ ]
   Other ……

5. **Number of Persons in Household**: Adult (s): Male [ ]
   Female [ ]
   Children: Male [ ]
   Female [ ]

6. **How long has the household lived in this community**?
   0-4yrs [ ]
   5-9 [ ]
   10-14 [ ]
   15 years and above [ ]

7. **Level of Education**:
   Never Schooled [ ]
   Primary Education [ ]
   Junior High Education [ ]

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Senior High education [ ]

University [ ]

Other: ……

8. **Occupation Status**:

Employed [ ]

Unemployed [ ]

Self-Employed [ ]

Trader [ ]

Other (specify) ……...

9. **Income Level Range** $50-150 [ ] 150-250 [ ] 250-350 [ ]
350-450 [ ] 450-550 [ ] 550-650 [ ]
650-750 [ ] **Other: ……**

10. **Community Name:**

……

Section II: Management Practices

This section is aimed to evaluate solid waste management practices being used by some selected residents of Buchanan, Liberia. Please tick [√] the appropriate option or write short answers in the spaces provided

11. How do you dispose of your waste? Burn [ ] Bury [ ] Dump in Open [ ] Composting [ ]
12. Do you have a designated area for waste disposal? Yes [ ] No [ ]
13. If yes, please specify

_____

14. What do you use for pre-collection or temporary storage of wastes?

Metal bin [ ] Individual plastic [ ] Plastic bag [ ]

Oil Drum [ ] Old Bucket [ ] Other [ ]

15. Is there a collection system from your yard after temporary storage?

Yes [ ] No [ ]

16. If yes, who: Private collector [ ] BCC [ ] or EPA staff [ ]

Other_____

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17. How often is the waste collected from households by the service providers (if any)?

    Daily [ ]
    Every other day [ ]
    Weekly [ ]
    Twice a Week [ ]
    Not at all [ ]

18. How do you rate the waste collection service of the Private Collectors (if any)?

    Excellent [ ]
    Satisfactory [ ]
    Poor [ ]
    Other [ ]

19. Will you be willing to use your food and vegetable wastes for fertilizer production? Yes [ ] No [ ]
20. If yes, have you any idea about how food and vegetable wastes are converted into fertilizer? Yes [ ] No [ ]
21. If yes, briefly explain the process

    _____

22. Will you be willing to use your food and vegetable wastes for energy production?

    Yes [ ] No [ ]

23. If yes, have you any idea about how energy is generated from food and vegetable wastes?

    Yes [ ] No [ ]

24. If yes, briefly explain the process

    _____

25. Are there any public bins or communal areas for waste disposal near or in your community?

    Yes [ ] No [ ]

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26. How often are public bins in your community emptied?

Once a week [ ]

Twice a week [ ]

thrice a week [ ]

Everyday [ ]

Don't know [ ]

Other _____

27. Are the bins large enough to accommodate the households waste in the community? Yes [ ] No [ ]

28. Who is responsible for managing the solid waste generated in the community?

_____

29. Are you aware of any solid waste management strategies implemented in the county?

Yes [ ] No [ ]

30. If yes, which of the following are being promoted by the county?

Composting [ ]

Incineration /Burning [ ]

Burying [ ]

Dumpsites [ ]

Waste to Energy [ ]

31. Which of the following waste management strategies are common in your community?

Composting [ ]

Incineration /Burning [ ]

Burying [ ]

Dumpsites [ ]

Waste to Energy [ ]

Other [ ]

32. What is the most challenging problem faced in handling solid waste in the community?

Waste not collected frequently [ ]

Inadequate waste bin [ ]

No waste bins [ ]

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Expensive waste collection bills [ ]

Other _____

Section V: Willingness to Pay for wastes management services

33. Is there a system of paying for waste collection in your community?

Yes [ ] No [ ]

34. If yes, who do you pay to? _____

35. Are you willing to pay for solid wastes management services for your household?

yes [ ] no [ ]

36. How much are you willing to Pay?

$5 [ ]

$10 [ ]

$15 [ ]

$20 [ ]

Other [ ]

37. How often do you want to pay?

Daily [ ]

Weekly [ ]

Monthly [ ]

Other _____

38. How often do you want the waste to be collected?

Weekly [ ]

Twice a week [ ]

Other _____

39. Which services are you hoping to receive for the payment you will make?

_____

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