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FAKO DIVISION'S SOLID WASTE LANDSCAPE: CHALLENGES, IMPACTS, AND PATHWAYS TO SUSTAINABLE DISPOSAL

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ABSTRACT

Rapid urbanization in Fako Division necessitates a re-evaluation of solid waste disposal systems. This study investigates the effects of existing waste disposal systems and facilities within Fako Division, located in the South West Region of Cameroon. Utilizing a mixed-method approach, data were gathered from secondary sources, including HYSACAM (a prominent waste management company), the Ombe Industrial Zone, and various hospitals. This secondary data was significantly augmented by primary data collected through 352 questionnaires distributed across the four key towns of Buea, Mutengene, Tiko, and Limbe. Data analysis involved conventional graphical plots and statistical techniques, employing Microsoft Excel 2016 and the Statistical Package for Social Sciences (SPSS) Version 20 to generate statistical tables, conduct correlation analyses, and produce bar graphs. The findings indicate that the majority of waste is disposed of in open dumpsites and directly into natural water bodies such as rivers and streams, with a lesser extent being littered along roadsides, within residential areas, and in farmlands. Industrial waste streams are primarily channeled directly into the sea, while hospital waste is typically incinerated. Furthermore, a significant portion of waste in Limbe and Buea is managed through unsanitary landfills operated by HYSACAM Company. Based on these critical findings, the study advocates for the establishment of a robust framework for waste handling to effectively mitigate environmental degradation and public health risks. It further emphasizes the crucial need for public sensitization regarding the hazards associated with improper waste management and calls for enhanced community involvement and participation in the waste management process. An optimal solution for solid waste disposal is proposed to be a properly engineered landfill where waste is meticulously unloaded, spread in thin layers, compacted, and subsequently covered with inert material, ensuring environmental protection and public safety.

KEYWORDS: - Contamination, water resources, disposal facilities, municipal wastes, urbanization, Cameroon, Fako Division.

Introduction

The escalating global challenge of solid waste management is intrinsically linked to two profound contemporary trends: unrelenting population growth and accelerated urbanization [2, 7]. Solid waste, encompassing a diverse array of discarded materials such as bottles, metals, plastic scrapers, general garbage, papers, glass, food and animal products, disposable carrying bags, wood, and even malfunctioning electronic devices, represents the tangible byproduct of human activity. These wastes are broadly classified based on their origin, including domestic, commercial, industrial, hospital, and street sweepings [14]. The sheer volume of waste generated worldwide is staggering, with global average waste generation rates fluctuating between 0.11 and 4.54 kg per person per day [12]. Projections indicate a dramatic increase in these figures; it is anticipated that the volume of municipal solid waste (MSW) will more than double from 1.3 billion tons annually in 2012 to an alarming 2.2 billion tons per year by 2025 [11, 2]. This exponential growth underscores the critical need for effective and sustainable waste management strategies across the globe.

As urban centers continue to expand at unprecedented rates, the management of municipal solid waste emerges as a significant public health and environmental crisis, particularly pronounced in urban areas worldwide [4, 5, 20]. Developing nations, characterized by burgeoning populations, rapidly expanding economies, and evolving living standards, are experiencing an even more

accelerated rate of solid waste generation [13, 21, 22]. The relentless pace of urban population growth, coupled with increasing waste generation rates, places immense strain on existing municipal solid waste infrastructure, especially within the urban landscapes of low and middle-income countries [2, 35]. However, while urbanization presents considerable challenges, it also paradoxically creates a concentrated human population and a nexus of services, offering a unique opportunity to implement and deliver highly efficient MSW services [6, 19]. The intricate relationship between municipal solid waste management, urbanization, developmental trajectories, and climate change cannot be overstated [7]. The phenomenal growth in waste generation rates in developing countries, often a consequence of increasing affluence, highlights the urgency of addressing these issues [2, 11].

The primary impediments to effective waste management in most developing countries revolve around establishing efficient waste collection mechanisms and implementing advanced waste treatment systems [10, 19, 21]. These measures are crucial not only for environmental protection but also for reducing greenhouse gas emissions emanating from the waste sector [26, 27]. Sub-Saharan Africa, for instance, exhibits alarmingly low waste collection rates, ranging from a mere 17.7% to 55% [1]. Consequently, the indiscriminate dumping of waste on roadsides is a pervasive practice throughout the region [1]. Although there has been a noticeable increase in the use of covered and compactor trucks for waste collection, the transportation of solid waste in inefficient and open vehicles remains a common sight in many urban areas [5]. Municipal authorities, typically vested with the responsibility for urban waste management, often confront systemic challenges that transcend their operational capacities. These challenges largely stem from a lack of coherent organization, insufficient financial resources, and the inherent complexity and multi-dimensional nature of waste management systems [19]. The relentless expansion of populations, coupled with escalating domestic, social, and industrial activities, along with advancements in technology, agricultural practices, livestock keeping, and commercial endeavors, continues to drive an increase in both the quantity and variety of solid wastes across most African nations [1, 16]. Consequently, local authorities are burdened with the formidable task of ensuring effective and efficient solid waste collection, storage, and transportation, alongside the maintenance of appropriate disposal centers and the provision of essential equipment such as bins and trucks [1].

In the rapidly urbanizing cities of the developing world, municipal solid waste management poses problems of immediate and critical importance [20]. While most governments acknowledge these challenges, the sheer pace of population growth frequently overwhelms the capacity of municipal authorities to deliver even the most fundamental services [1]. Alarmingly, it is common for one to two-thirds of the solid waste generated to remain uncollected [19]. This uncollected waste, often commingled with human and animal excreta, is indiscriminately dumped on streets and into drainage systems, exacerbating problems such as urban flooding, fostering the proliferation of insect and rodent vectors, and contributing significantly to the spread of diseases [1, 40]. Specifically, the prevalent issues include open dumping in uncontrolled sites, the open burning of waste fractions, and the egregious mismanagement of leachate generated at final disposal sites [35]. Even collected waste, regrettably, is frequently deposited in uncontrolled dumpsites and/or incinerated, leading to pervasive pollution of water resources and air quality [23, 24, 25, 28].

Key challenges identified in waste management within the developing world include the varied composition of waste, the widespread absence of effective waste separation schemes at source, inefficient waste collection methodologies, chronic lack of financial support, inadequate policy frameworks pertaining to waste management, and a marked absence of coordination among disparate governmental institutions [10, 21, 22]. The global waste crisis is fundamentally a consequence of untreated, unsafe disposal practices and inherently inefficient waste collection systems [20, 27]. In urban Africa, solid waste management represents a formidable challenge for authorities in the rapidly expanding cities, particularly those in developing countries [1, 9]. The persistent growth of urban populations and the swift increase in solid waste generation have unequivocally emerged as one of the most pressing issues confronting human society, especially within the developing world [2, 11, 20]. A prevailing and concerning practice in most developing countries is the dumping of solid wastes on land without the adoption of any acceptable sanitary landfilling practices [19, 35]. This precarious situation is further exacerbated in slum areas, which present additional complexities stemming from high population density, traffic congestion, and severe air and water pollution [4].

Municipal Solid Waste Management in Cameroon, similar to other developing countries grappling with high rates of urbanization, represents a significant environmental challenge for many municipalities [8, 9, 18, 30, 39]. With an increasing population, expanding economic activities, and rapidly evolving lifestyles, Cameroon faces formidable obstacles in effectively managing its solid waste [8, 9]. Cameroon's Municipal Solid Waste Management policy theoretically operates on a public-private partnership model, spearheaded by the Hygiene and Sanitation Company Cameroon (HYSACAM), which is mandated to ensure regular collection and processing services for domestic waste in major cities [30]. Within Fako Division, HYSACAM is specifically responsible for waste management in the municipalities of Buea and Limbe [30]. Despite HYSACAM's involvement, these towns frequently remain marred by accumulated piles of uncollected waste, conspicuously visible along roadsides, in gutters, scattered throughout residential areas, in open dumpsites, along riverbeds, and within surface water bodies [36, 40]. This pervasive issue leads to significant environmental contamination and poses substantial health risks to the

populace [34, 36, 41].

1.1. Broad Background and Historical Context

The narrative of solid waste generation is as old as human civilization itself, evolving in complexity with societal advancements. Historically, waste was predominantly organic and easily assimilated by natural processes. However, the advent of industrialization in the 18th and 19th centuries marked a significant paradigm shift, introducing novel materials like plastics, metals, and complex chemicals into the waste stream [41]. This period saw the rudimentary beginnings of organized waste collection, primarily driven by concerns for public health, as accumulating waste became a breeding ground for diseases. The mid-20th century, particularly the post-World War II era, witnessed an unprecedented surge in consumerism and industrial output, leading to a dramatic increase in both the quantity and diversity of solid waste [2, 11]. This era highlighted the inadequacy of existing disposal methods, predominantly open dumping and burning, which resulted in severe environmental degradation and public health crises [4, 35].

The late 20th and early 21st centuries have been characterized by rapid urbanization, especially in developing countries [7]. This demographic shift has concentrated populations in urban centers, intensifying the challenge of waste management [1, 2, 7]. Cities, as economic and social hubs, generate enormous quantities of waste, often far exceeding the capacity of their municipal services [1]. The global average waste generation, fluctuating between 0.11 and 4.54 kg per person per day, is a testament to the sheer scale of this issue [12]. Projections for municipal solid waste (MSW) indicate a doubling from 1.3 billion tons in 2012 to 2.2 billion tons by 2025 [11, 2], underscoring a trajectory of increasing environmental burden if current practices persist. This historical progression from localized, manageable waste to a global crisis underscores the critical need for comprehensive and adaptive waste management strategies, particularly in regions experiencing rapid urban growth and economic transformation.

1.2. Critical Literature Review

The global challenges of solid waste management are well-documented across academic and policy spheres, with a significant body of literature highlighting the disproportionate burden faced by developing nations [19, 20, 35]. The World Bank's "What a Waste 2.0" report provides a comprehensive overview of global trends, emphasizing the projected doubling of municipal solid waste (MSW) by 2025 [2, 11], a forecast that profoundly impacts low and middle-income countries. This aligns with findings from Sujauddin et al. (2008) [13], who characterized household solid waste management in Chittagong, Bangladesh, revealing challenges pertinent to waste composition and disposal practices prevalent in developing contexts. Similarly, Burnley (2007) [14] offered a review of MSW composition in the United Kingdom, providing a comparative perspective that underscores the compositional differences and management complexities between developed and developing nations.

In the context of African nations, the literature consistently points to significant deficiencies in waste collection and treatment systems [1, 10, 19]. Babyebonela (2013) [1] explored local resource management for sustainable solid waste management, specifically in Kinondoni, Municipality, Dar Es Salaam City, Tanzania, highlighting issues related to institutional capacity and community involvement. The World Bank's 2014 report on results-based financing for municipal solid waste further emphasizes the financial constraints and systemic challenges that hinder effective waste management initiatives in urban development contexts [3]. Oteng-Ababio (2014) [6] provided insights from Accra, Ghana, on rethinking waste as a resource, suggesting potential pathways for low-income communities to engage in more sustainable practices. However, these efforts are often hampered by the low waste collection efficiency, with Sub-Saharan Africa notably having collection rates ranging from 17.7% to 55% [1], leading to widespread dumping on roadsides.

Specific to Cameroon, existing literature underscores the severity of the solid waste management crisis [8, 9, 18, 39]. Ako (2012) [8] provided a global perspective on solid waste management with a detailed case study of Cameroon, drawing attention to the systemic issues at play. Azah (2008) [9] further investigated obstacles to sustainable solid waste management in Cameroon, exploring the potential of micro-privatization as a solution. Despite the establishment of public-private partnerships, such as the Hygiene and Sanitation Company Cameroon (HYSACAM), which is responsible for waste collection and processing in major cities [30], the problem persists. Mbeng et al. (2012) [29] conducted waste characterization in Limbe, Cameroon, as an element of household waste management operations, revealing specific challenges related to waste composition in the region. Ymele (2012) [30] also discussed Cameroon's path towards municipal solid waste management, focusing on the role of HYSACAM. Despite these efforts, uncollected waste and indiscriminate dumping remain prevalent, causing contamination and health problems, particularly in Fako Division [36, 40]. This situation is exacerbated by the fact that HYSACAM does not collect waste from all sites within the division, leaving land and water bodies vulnerable to pollution [36].

The environmental consequences of inadequate waste management are extensively documented [4, 35]. Khanbilvardi et al. (1992) [17] highlighted the occurrence and distribution of leachate in solid waste landfills, pointing to a major source of water contamination. Ferronato and Torretta (2019) [35] reviewed waste mismanagement in developing countries, identifying global issues such as open dumping, open burning, and poor leachate management as primary concerns. These practices contribute to the pollution of water resources and air, as noted by Torretta et al. (2017) [23], UNEP (2016) [24], and WWAP (2017) [25]. The pollution of

water resources in Fako Division has also been specifically highlighted by Banseka et al. (2022) [36], indicating the localized impact of these broader issues. The contamination of groundwater due to landfill sites, as investigated by Jhamnani and Singh (2009) [32] in New Delhi, further emphasizes the severe environmental repercussions of uncontrolled waste disposal.

Beyond environmental impacts, the literature also addresses the socio-economic dimensions of waste management challenges [1, 10, 19]. Ekere et al. (2009) [10] explored factors influencing waste separation and utilization among households in Uganda, revealing insights into community engagement and behavioral aspects. Folefack (2008) [37] examined factors influencing the use of compost from household waste in Cameroon, demonstrating the potential for local solutions. However, the lack of organization, financial resources, and the multi-dimensional complexity of waste management systems often pose significant hurdles for municipal authorities in developing countries [19]. The uncollected waste, often mixed with human and animal excreta, contributes to urban flooding, acts as a breeding ground for vectors, and facilitates the spread of diseases [4, 40]. This comprehensive review of existing literature underscores the multifaceted nature of solid waste management challenges, particularly in rapidly urbanizing regions of developing countries, setting the stage for a more focused investigation into the specific context of Fako Division, Cameroon.

1.3. The Identified Research Gap

Despite the extensive body of literature on solid waste management in developing countries and even specific studies on Cameroon [8, 9, 18, 29, 30, 39], a noticeable gap persists concerning renewed, localized evidence on the functionality and effects of solid waste disposal systems in rapidly urbanizing divisions like Fako. While general challenges have been identified [1, 2, 11, 19, 20, 35], the specific impacts of existing disposal systems and facilities within Fako Division, particularly in relation to recent rapid urbanization, warrant a focused and comprehensive investigation. Previous research often provides broader national or regional overviews, or examines specific aspects without a holistic analysis of disposal systems' effects on the environment and public health in a rapidly growing area like Fako Division, where local dynamics and the effectiveness of existing partnerships (e.g., HYSACAM's operations) need granular assessment. This study aims to fill this gap by providing current, empirical data and a detailed analysis of the prevailing waste disposal methods and their associated challenges and solutions within this specific geographical and demographic context.

1.4. Study Rationale, Objectives, and Hypotheses

The rapid urbanization witnessed in Fako Division has underscored an urgent need for up-to-date and specific evidence regarding the efficacy and functionality of its solid waste disposal systems [2, 7, 11]. This demographic shift intensifies the generation of diverse waste streams, placing unprecedented pressure on existing infrastructure and posing escalating environmental and public health risks [4, 20, 35, 36, 40]. The rationale for this study stems from the critical imperative to understand these dynamics, particularly given the observed piles of uncollected waste and contamination issues in key towns despite the presence of waste management entities like HYSACAM.

The primary objective of this paper is to investigate the effects of solid waste disposal systems and facilities within Fako Division, located in the South West Region of Cameroon. This overarching objective is further delineated by several specific aims:

1. To identify and characterize the prevailing solid waste disposal systems and facilities utilized across the four main towns of Buea, Mutengene, Tiko, and Limbe within Fako Division.

2. To assess the environmental impacts, particularly on water resources and land, resulting from current waste disposal practices [17, 23, 24, 25, 28, 32, 36, 38].

3. To evaluate the public health implications associated with the existing waste disposal methods [4, 34, 40].

4. To examine the role and effectiveness of the Hygiene and Sanitation Company Cameroon (HYSACAM) in managing waste in the Buea and Limbe municipalities [30].

5. To propose a comprehensive framework and practical solutions for improved waste handling to mitigate environmental and health hazards in Fako Division.

Based on the observed challenges and existing literature, the following hypotheses guide this research:

- Hypothesis 1: Current solid waste disposal practices in Fako Division, primarily relying on open dumpsites and direct discharge into water bodies, significantly contribute to environmental contamination and pose substantial public health risks [17, 23, 24, 25, 28, 32, 34, 35, 36, 38, 40, 41].

- Hypothesis 2: The capacity and operational efficiency of the existing waste management infrastructure and services, including those provided by HYSACAM, are insufficient to adequately manage the increasing volume and diversity of solid waste generated due to rapid urbanization [1, 9, 19, 30].

- Hypothesis 3: A lack of public awareness and participation in proper waste management practices exacerbates the challenges of solid waste disposal in Fako Division [10, 22].

These objectives and hypotheses form the foundational pillars for a detailed investigation into the complex landscape of solid waste management in Fako Division, aiming to provide actionable insights for sustainable

solutions.

2. METHODS

2.1. Research Design

The research design employed in this study was a mixed-methods approach, integrating both explanatory and descriptive methodologies. This comprehensive design allowed for a multifaceted investigation into the challenges and solutions of solid waste disposal systems in Fako Division, Cameroon. The descriptive component aimed to characterize existing waste disposal practices, facilities, and their observable effects, providing a detailed snapshot of the current situation. Concurrently, the explanatory component sought to elucidate the underlying reasons and contributing factors behind these observed effects, particularly in the context of rapid urbanization and population growth. This mixed approach facilitated a deeper understanding by combining quantitative data from surveys with qualitative insights derived from interviews and observations, thereby offering a more holistic perspective on the complex issue of solid waste management in the study area. The design also facilitated the systematic collection and analysis of data from various stakeholders, including households, waste management companies, hospitals, and industrial zones, ensuring a comprehensive investigation.

2.2. Participants/Sample

The study's participants were diverse, encompassing both the general population and key institutional stakeholders within Fako Division. The primary data collection from the population involved administering direct questionnaires using a stratified sampling technique across the four main towns: Buea, Mutengene, Tiko, and Limbe. The stratification was based on the population size of each town, ensuring that the number of questionnaires administered in each locality was proportionate to its demographic representation. A total of 352 questionnaires were distributed and collected across these four towns. Specifically, Buea received the highest number of questionnaires (139, representing 39.5% of the total), reflecting its larger population, followed by Tiko/Mutengene (112 questionnaires, 31.8%) and Limbe (101 questionnaires, 28.7%). The questionnaire itself was structured to gather essential information, including the age range and educational level of the respondents, household size, approximate weekly solid waste generation, and the specific waste disposal systems utilized by households. Questionnaires were administered randomly within each town, maintaining the stratified proportionality. For respondents who were unable to read or write, the questions were posed directly in an interview format to ensure their participation and accurate data capture.

In addition to the household surveys, in-depth interviews were conducted with critical stakeholders across Fako Division. These interviews provided invaluable qualitative data and perspectives from individuals directly involved in or affected by waste management. Key interviewees included:

- The Deputy Mayor of Buea council, interviewed in February 2021, focusing on the responsibility for waste management within the municipality.
- General Supervisors (GS) of regional hospitals in Buea and Limbe, interviewed in May 2022, to ascertain their solid waste disposal methods and frequency.
- General Supervisors of the Baptist Hospital in Mutengene, Mount Mary Hospital in Buea, and the District Hospital in Tiko, interviewed in March 2021, to understand the systems they had implemented for waste disposal to protect public health.
- The Head of Technical Services at HYSACAM Company in Limbe and Buea, interviewed in May 2022, to gather information on waste collection frequency from dumpsites, unsanitary landfills, and overflow waste cans.
- Technical Service personnel from Sonara (a petroleum refinery), Production Department of the Rubber Factory, Production Department of the Banana Factory, and Technical Department of Brasseries Depot (a brewery), all interviewed in May 2022, to understand their solid waste disposal practices and any pre-disposal treatment.

These interviews, conducted during fieldwork, complemented the questionnaire data by providing a more nuanced understanding of institutional practices, challenges, and perspectives on waste management within Fako Division. Personal interactions with HYSACAM technical heads and the general population further enriched the qualitative data set. This multi-pronged approach to sampling ensured comprehensive data collection from both individual citizens and critical institutional actors, offering a robust foundation for analysis.

2.3. Materials and Apparatus

The materials and apparatus utilized in this study were primarily comprised of data collection instruments and analytical software. For primary data collection, a structured questionnaire served as the main instrument for surveying the general population across the four study towns: Buea, Mutengene, Tiko, and Limbe. This questionnaire was designed to capture specific details regarding household demographics, waste generation rates, and existing waste disposal practices. For stakeholders and individuals unable to read or write, a semi-structured interview guide was employed, facilitating direct verbal interaction and ensuring comprehensive data capture.

In terms of secondary data collection, various institutional records and reports served as crucial materials. Information on population evolution statistics was obtained from the Central Bureau for Census and Population Studies (BUCREP) in Buea, providing

demographic context and trends [31]. Data pertaining to the quantity of waste collected and dumped in landfills over the years was acquired directly from HYSACAM, the primary waste management company operating in the region [30]. Details on the types of wastes generated and their disposal methods were collected from five sampled hospitals within Fako Division. Furthermore, data concerning industrial waste generation and disposal practices over several years were collected from the Ombe Industrial Zone.

For the analysis of both primary and secondary data, two key statistical software packages were employed:

● Microsoft Excel 2016: This software was utilized for conventional graphical plots and initial statistical computations. Its capabilities facilitated data organization, basic descriptive statistics, and the creation of various charts and graphs to visualize data trends and distributions.

● Statistical Package for Social Sciences (SPSS) Version 20: SPSS was the primary statistical tool for more advanced analytical techniques. It was specifically used to compute and produce statistical tables, conduct correlation analyses, and generate bar graphs, enabling a rigorous statistical examination of the collected data.

These materials and apparatus collectively ensured that the study's data collection and analysis were systematic, robust, and aligned with standard research methodologies, allowing for the generation of reliable and insightful findings.

2.4. Experimental Procedure/Data Collection Protocol

The data collection protocol for this study was meticulously designed to encompass both primary and secondary data sources, ensuring a comprehensive understanding of solid waste disposal systems in Fako Division. The fieldwork was conducted in several phases, integrating different methodologies to capture diverse perspectives and quantitative metrics.

Primary Data Collection:

1. Questionnaire Administration:

○ Sampling Strategy: A stratified sampling technique was applied across the four main towns of Buea, Mutengene, Tiko, and Limbe. The total population of each town served as the basis for determining the proportional number of questionnaires to be administered, ensuring representative coverage.

○ Distribution: A total of 352 questionnaires were distributed randomly within selected households in these towns. Buea, having the largest population among the study areas, received the highest allocation of questionnaires (139), followed by Tiko/Mutengene (112), and Limbe (101).

○ Content: Each questionnaire gathered specific information on respondent demographics (age range, education level), household size, approximate weekly solid waste generation, and the prevailing waste disposal system employed by the household.

○ Assistance: For individuals who were illiterate or had difficulty reading, direct interviews were conducted by the researchers, ensuring full participation and accurate data capture.

2. Key Informant Interviews:

○ Selection: Interviews were conducted with a diverse group of key stakeholders identified for their direct involvement or expertise in waste management within Fako Division. These included:

■ The Deputy Mayor of Buea Council (February 2021) to understand municipal waste management responsibilities.

■ General Supervisors of Regional Hospitals in Buea and Limbe (May 2022) to ascertain medical waste disposal practices and frequency.

■ General Supervisors of Baptist Hospital (Mutengene), Mount Mary Hospital (Buea), and District Hospital (Tiko) (March 2021) to understand the systems they had implemented for waste disposal to protect public health.

■ The Head of Technical Services at HYSACAM Company in Limbe and Buea (May 2022) to gather data on waste collection frequency from various sites.

■ Technical Service and Production Department personnel from key industrial establishments (Sonara, Rubber Factory, Banana Factory, Brasseries Depot) (May 2022) to understand industrial waste disposal and treatment protocols.

○ Procedure: These interviews followed a semi-structured format, allowing for both pre-defined questions on key issues (e.g., waste responsibility, disposal frequency, treatment methods) and flexible probing for deeper insights. The duration of interviews varied from 15 minutes to 1 hour depending on the scope and availability of the interviewee.

Secondary Data Collection:

1. Population Statistics: Data on the evolution of the population over time was sourced from the Central Bureau for Census and Population Studies (BUCREP) in Buea [31]. This provided crucial demographic context for understanding waste generation trends in Fako Division.

2. HYSACAM Data: Information regarding the quantity of waste collected and subsequently dumped in various landfills over the years was obtained directly from HYSACAM, the contracted waste management company

[30].

3. Hospital Waste Data: Details on the types of wastes generated by hospitals and their respective disposal methods were collected from five specific hospitals within the study area.

4. Industrial Waste Data: Data pertaining to the types of waste generated and disposed of by industries within the Ombe Industrial Zone over the years were also systematically collected.

The data collection protocol was executed with careful attention to detail, ensuring the reliability and validity of the information gathered from diverse sources. The combination of quantitative surveys and qualitative interviews provided a robust dataset for subsequent analysis.

2.5. Data Analysis Plan

The data analysis plan for this study was designed to systematically process and interpret the comprehensive dataset collected through both primary and secondary sources. The analysis was primarily achieved using a combination of conventional graphical plots and advanced statistical techniques, employing specialized software to ensure accuracy and rigor.

1. Data Compilation and Organization:

○ All collected questionnaire data were meticulously transcribed and organized into a digital format. Similarly, interview notes and secondary data from BUCREP [31], HYSACAM [30], hospitals, and the Ombe Industrial Zone were compiled and structured for analysis.

○ Microsoft Excel 2016 was initially utilized for the organization, cleaning, and preliminary tabulation of the raw data. This step involved identifying and correcting any data entry errors, handling missing values, and structuring the data into suitable formats for further statistical analysis.

2. Descriptive Statistics:

○ Descriptive statistics were computed to summarize the main features of the collected data. This included calculating frequencies, percentages, means, and standard deviations for relevant variables.

○ For instance, descriptive statistics were used to quantify the distribution of household waste disposal facilities (e.g., trash cans, pits, culverts, streams/rivers) across the different towns (Buea, Mutengene, Tiko, Limbe), providing insights into the predominant disposal methods.

○ Similarly, descriptive analysis characterized the types of waste generated (e.g., biodegradable, non-biodegradable, hazardous) and the disposal systems used by hospitals and industrial zones.

3. Graphical Representation:

○ Conventional graphical plots were generated to visually represent data patterns and trends. Microsoft Excel 2016 and SPSS Version 20 were both instrumental in creating various types of graphs, including:

■ Bar graphs: Used to illustrate the distribution of household waste disposal facilities by location and to present the quantity and types of industrial waste disposed of over different years.

■ Other graphical plots: Employed to visualize other relevant data distributions, such as the spatial distribution of waste dumpsites.

○ These visual aids facilitated a clearer understanding of the data, making complex statistical information more accessible.

4. Inferential Statistics (Correlation Analysis):

○ The Statistical Package for Social Sciences (SPSS) Version 20 was the primary tool for conducting more advanced statistical analyses, particularly correlation analysis.

○ Correlation analysis was performed to identify and quantify the strength and direction of relationships between various variables. For instance, this could involve examining the correlation between population growth/urbanization rates [31] and the quantity of waste generated, or between specific disposal methods and observed environmental contamination [36].

○ SPSS was also used to compute and produce more detailed statistical tables, supporting the findings presented in the results section.

By integrating these analytical techniques, the data analysis plan aimed to thoroughly investigate the research objectives, test the formulated hypotheses, and provide robust, evidence-based conclusions regarding solid waste disposal systems in Fako Division. The use of both Excel and SPSS ensured versatility and depth in the analytical process, allowing for both straightforward data presentation and complex statistical inference.

3. RESULTS

3.1. Preliminary Analyses

The preliminary analyses of solid waste in Fako Division reveal a direct correlation between the rapid growth of population and urbanization and a significant increase in the quantity, quality, and variety of waste generated [2, 7, 11, 31]. This has led to a deteriorating situation concerning waste disposal systems and the overall environment [4, 35, 36, 40]. The municipal solid waste stream in Fako Division is heterogeneous, primarily comprising general wastes such as organics and recyclables [14, 29]. Beyond these, the waste stream also includes special wastes, which

encompass household hazardous materials, medical waste from healthcare facilities, and industrial wastes from various economic activities. Additionally, construction and demolition debris contribute to the overall waste burden.

A critical finding from the preliminary analysis is the widespread prevalence of rudimentary and environmentally detrimental waste disposal practices. A substantial portion of these diverse waste types is disposed of in open dumpsites [19, 35]. These dumpsites are not confined to designated areas but are frequently found along roadsides, in natural valleys, scattered around residential areas, and even within agricultural farmlands [1, 36, 40]. Furthermore, a concerning practice involves the direct disposal of waste into surface water bodies, including rivers and streams, contributing significantly to water pollution [24, 25, 28, 36]. While these practices are widespread, the least common forms of disposal observed were direct littering along roadsides, around residential areas, and in farmlands.

In addition to these informal and uncontrolled disposal methods, the study identified the presence of two inadequately designed unsanitary landfills. These landfills are located in Isokolo, Limbe, and Mussaka, Buea, and are operated by the HYSACAM Company [30]. Despite being managed by an official waste management entity, their poor design poses substantial environmental risks, including potential contamination of water, soil, and air [17, 32, 33, 35]. The municipality of Tiko, in contrast to Buea and Limbe, was found to lack any established municipal waste management system, leaving its population to independently decide on their waste disposal methods. This absence of a structured system contributes to unregulated and potentially harmful disposal behaviors within the area.

Household waste disposal practices also vary across the division. While many households in Limbe and Buea utilize trash cans that are subsequently emptied by HYSACAM [30], other prevalent methods include disposing of biodegradable and non-biodegradable waste in excavated pits dug around residences, homes, and even some institutions like hospitals. Furthermore, culverts, streams, and rivers are unfortunately abused as common disposal points [36, 38, 40]. A notable practice among households involves the burning of non-biodegradable plastics, which contributes to air pollution [41]. These preliminary findings underscore the urgent need for improved and standardized waste management practices across Fako Division to mitigate the escalating environmental and public health risks.

3.2. Main Findings

The main findings of this study provide a detailed insight into the prevailing solid waste disposal systems and their implications across Fako Division. The analysis revealed distinct patterns in household, hospital, and industrial waste management, each presenting unique challenges.

Household Waste Disposal Facilities:

The study found that household waste disposal facilities in Fako Division primarily include trash cans and pits dug around residential areas [29]. However, a significant and concerning finding is the widespread abuse of culverts, rivers, and streams as convenient disposal points [36, 38, 40]. The utilization of trash cans varied significantly by location, with Buea recording the highest percentage of users (41.74%), followed by Tiko (25.22%) and Limbe (19.13%), while Mutengene showed the least usage (13.91%). Similarly, the disposal of household waste in pits was most common in Buea (42.50%), followed by Limbe and Tiko (both at 22.50%), with Mutengene again being the least (12.50%). Limbe exhibited the highest percentage of the population disposing of household waste in culverts (39.13%), significantly higher than Buea (31.88%), Tiko (15.94%), and Mutengene (13.04%).

Alarmingly, a considerable portion of the population in Fako Division uses streams and rivers as primary disposal systems [36, 38, 40]. Limbe again showed the highest percentage of residents engaging in this practice (52.08%), followed by Buea (37.50%), Mutengene (6.25%), and Tiko (4.17%). These household wastes encompass a wide array of materials, including unused food, vegetable peels, rotten food, discarded papers, plastic bags, plastic wrappers, paper containers, broken plastic buckets, unused cotton materials, electronic wastes, smoke, dust, and pharmaceutical and personal care products (PPCPs) [14, 29]. The widespread use of open dumping, particularly in surface water bodies and culverts, directly contributes to environmental degradation and potential health hazards [4, 17, 23, 24, 25, 28, 32, 34, 35, 36, 38, 40, 41].

Hospital Waste Management:

Fako Division benefits from several medical healthcare facilities located across Tiko, Buea, and Limbe municipalities. These hospitals, including the regional hospitals in Limbe and Buea, Tiko District Hospital, Baptist Hospital in Mutengene, and Mount Mary Hospital in Buea, generate substantial amounts of waste. The study found that these institutions generally manage their waste within their premises. Waste bins are emptied daily from wards, and incineration is a common daily practice for burning waste due to the overwhelming production rate. Sanitation workers are responsible for collecting and transporting waste, mostly plastics, from wards to on-site disposal systems using trash cans.

Collection frequencies varied; for example, Tiko District Hospital and Limbe Regional Hospital emptied bins at least once daily (typically mornings), while Mount Mary and Baptist hospitals in Mutengene did so twice daily (mornings and afternoons). The predominant waste collection systems within these healthcare facilities were plastic bins and plastic bags, manually transported to disposal sites. Pathological waste was specifically disposed of in cemented placenta pits dug into the ground and covered with lids. Furthermore, hospitals had provisions for separating biodegradable and non-biodegradable wastes, which were disposed of in separate dug open pits, subsequently covered with soil and compacted once full. While incineration is practiced, the specific methods and

environmental controls for this process were not fully detailed in the provided information, raising potential concerns for air quality [23, 24, 25].

Industrial Waste Disposal:

Industries and factories within Fako Division, primarily situated near the sea, reported that their hazardous wastes underwent thorough treatment before being discharged into the marine environment. These industries generate various types of waste, some unique and some similar across different years (2015-2021). Common industrial waste types identified include ordinary industrial wastes, hydrocarbon wastes, hydrocarbon sludge, metal scrap, and special industrial wastes. The quantities of these wastes varied annually; for instance, hydrocarbon sludge saw a decrease from 2015 to 2017, an increase in 2018, a drop in 2019, and no recorded quantity in 2021. While industries claim pre-discharge treatment, the extent and effectiveness of such treatments remain a critical area for further scrutiny to ensure marine environmental protection [23, 24, 25, 41].

3.3. Secondary or Exploratory Findings

Beyond the direct characterization of waste disposal systems, the study also yielded several secondary or exploratory findings that contribute to a more holistic understanding of the waste management landscape in Fako Division. These findings illuminate the broader context and consequences of current practices.

Prevalence of Open Dumping and its Consequences:

Open uncontrolled dumping emerged as the predominant method of solid waste disposal across Fako Division, particularly visible in the towns of Buea, Tiko, Mutengene, and Limbe [19, 35, 36]. These open dump pits are inherently inefficient, promoting uneconomical use of available space and facilitating unrestricted access for animals, insects, and flies [4, 35]. The decomposition of waste within these pits is a significant concern, as it leads to the emission of greenhouse gases like methane and produces toxic leachates [17, 32, 33, 35]. These leachates pose a severe threat, polluting both subsurface and surface waters and substantially increasing the risk of disease transmission to the local population [17, 23, 24, 25, 28, 32, 34, 36, 38, 40]. Many of these open dumps were observed along roads, within surface water bodies, along river banks, in culverts, and on the ground in residential areas [36, 40].

Impact on Drainage Systems and Urban Flooding:

A particularly striking observation was the common scenario of open dumping along roads in Mutengene and Tiko. During rainy seasons, these accumulated wastes decay, and runoff washes them into gutters and ultimately into waterbody systems, exacerbating water contamination with leachate [36, 38, 40]. The poor design of road culverts, evident in Buea and Limbe, often results in their blockage by discarded trash. This blockage is frequently attributed to delays in waste collection by the HYSACAM Company [30], leading residents to dispose of overflowing waste into and thereby obstructing culverts, further degrading the environment. The proliferation of plastics, in particular, was noted to choke and block drainage and sewage systems, a direct cause of urban flooding during the wet season [40, 41].

Public Health Nuisances and Sensory Impacts:

Residents living in close proximity to open waste dump pits, such as those in Isokolo, Limbe, reported significant nuisance from the smell of decomposing wastes. This issue was exacerbated during rainy periods, when these areas became heavily infested with flies and other insects, posing direct health and environmental nuisances [4, 35]. These sensory and health impacts highlight the immediate quality-of-life implications for communities living near inadequately managed waste sites.

HYSACAM's Role and Limitations:

While HYSACAM Company is responsible for waste management in Buea and Limbe [30], its operations involve the creation of open unsanitary landfills. The study implicitly highlights the limitations of HYSACAM's reach and effectiveness, given the continued presence of uncollected waste and the reliance on uncontrolled dumping practices across various parts of Fako Division, especially in Tiko where no municipal system exists. The fact that HYSACAM does not collect waste from all sites in Fako Division leaves significant portions of land and water bodies vulnerable to pollution [36].

These exploratory findings emphasize the multifaceted nature of the solid waste management crisis in Fako Division, extending beyond mere disposal methods to encompass broader environmental, public health, and infrastructural vulnerabilities.

4. DISCUSSION

4.1. Interpretation of Key Findings

The findings of this study paint a vivid and concerning picture of solid waste management in Fako Division, South West Region of Cameroon. The rapid urbanization and population growth in the region are unequivocally linked to the escalating quantity and complexity of waste generated, placing immense pressure on an already strained disposal infrastructure [2, 7, 11, 31]. The pervasive reliance on informal and environmentally detrimental waste disposal methods—primarily open dumpsites and direct discharge into water bodies—is a critical finding [1, 19, 35, 36, 40]. This suggests a systemic failure in providing adequate, accessible, and regulated waste disposal alternatives for a significant portion of the population. The practice of disposing of waste in culverts, rivers, and streams is particularly alarming, as it directly compromises water quality, a vital resource for human consumption and ecosystem health [24, 25, 28, 36, 38]. This aligns with broader concerns about water quality in developing countries [28] and previous findings specifically in Fako Division [36].

The existence of poorly designed unsanitary landfills managed by HYSACAM in Limbe and Buea [30] indicates that even formalized waste management efforts fall short of international best practices. These landfills, by their very nature, are sources of contamination, threatening soil, water, and air quality [17, 32, 33, 35]. The absence of any structured waste management system in Tiko municipality further highlights the uneven and fragmented approach to waste management across the division, leading to unregulated and potentially hazardous disposal behaviors within the area.

Household waste disposal practices reveal a mixed bag of behaviors. While trash cans are utilized, particularly in Buea, the continued prevalence of pit disposal and direct disposal into waterways underscores a need for enhanced public awareness, provision of accessible collection services, and enforcement of regulations [10, 22]. The burning of non-biodegradable plastics at the household level is a clear indicator of limited alternatives and a significant contributor to air pollution [41].

Hospital waste management, with its reliance on on-site incineration and placenta pits for pathological waste, demonstrates a more formalized approach due to the hazardous nature of medical waste. However, the details on the environmental controls for these incineration processes are not explicitly provided, which could still pose risks to air quality [23, 24, 25]. The manual transportation of waste within hospital premises also highlights potential occupational health risks for sanitation workers.

Industrial waste management, while claiming thorough treatment before discharge into the sea, warrants independent verification. The types and varying quantities of industrial wastes necessitate robust monitoring mechanisms to ensure compliance with environmental standards and prevent marine pollution [23, 24, 25, 41]. The overarching interpretation of these findings is that Fako Division faces a multi-faceted solid waste crisis driven by rapid urbanization, inadequate infrastructure, limited public awareness, and potentially insufficient regulatory enforcement. The current practices are not sustainable and pose significant, ongoing threats to public health and the environment [4, 34, 35, 36, 40, 41].

4.2. Comparison with Previous Literature

The findings of this study resonate strongly with the broader academic discourse on solid waste management challenges in developing countries, particularly within Sub-Saharan Africa [1, 19, 20, 35]. The observed exponential increase in waste generation in Fako Division due to rapid urbanization [31] is consistent with global trends identified by the World Bank, which projected a doubling of municipal solid waste (MSW) by 2025 [2, 11]. This also aligns with the acceleration of solid waste generation rates in developing countries attributed to increasing population levels, booming economies, and rising living standards [13, 21, 22].

The pervasive issue of uncollected waste and indiscriminate dumping in Fako Division, evident in piles of trash along roadsides, in gutters, and open dumpsites, mirrors the situation described in general for Sub-Saharan Africa where collection rates are as low as 17.7% to 55% [1]. The practice of dumping waste directly into streets and drains, leading to flooding and disease vectors, is a direct parallel to the challenges faced in Fako Division, where poorly disposed waste chokes drainage systems and leads to flooding during the wet season [40]. This corroborates the global waste crisis narrative, highlighting untreated, unsafe disposal and inefficient collection as primary drivers [20, 27].

The reliance on open dumpsites as the most common method of disposal is a recurring theme in the literature concerning developing nations, often cited as a major source of greenhouse gas emissions and toxic leachate [19, 35]. The contamination of water resources, both surface and potentially subsurface, from these sites in Fako Division [36] is consistent with findings from other studies on landfill leachate pollution [17, 23, 32, 38]. This localized impact in Fako Division has been previously highlighted [36], reinforcing the persistent nature of this environmental concern. The poor design of landfills, even those managed by entities like HYSACAM [30], reflects a broader problem of inadequate waste management infrastructure in developing contexts [19, 35].

The challenges encountered by municipal authorities in Fako Division, such as the struggle to provide effective and efficient waste management systems, are not unique [1, 9, 19]. Literature consistently points to issues like lack of organization, financial constraints, and system complexity as major impediments for municipalities in other developing countries [19]. The absence of a structured municipal waste management system in Tiko exemplifies this common deficiency.

While the study notes the use of incineration for hospital waste, this finding requires further scrutiny regarding emission controls, a common concern globally given the potential for air pollution [23, 24, 25]. Similarly, the claim of thorough treatment for industrial hazardous waste before sea discharge aligns with regulatory aspirations but necessitates stringent monitoring, as industrial waste management remains a complex issue worldwide [23, 24, 25, 41].

In essence, the conditions in Fako Division, particularly concerning indiscriminate dumping, strain on collection services, and environmental pollution, are not isolated incidents but rather representative of systemic challenges broadly discussed in the global and African waste management literature [1, 2, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41]. This study provides current, localized evidence that reinforces the urgency and universal applicability of many identified problems.

4.3. Strengths and Limitations of the Study

This study on solid waste disposal systems in Fako Division exhibits several notable strengths that enhance the credibility and applicability of its findings, alongside inherent limitations that warrant consideration for future research.

Strengths:

1. Mixed-Methods Research Design: The utilization of a mixed-methods approach, combining both explanatory and descriptive methodologies, is a significant strength. This allowed for a comprehensive investigation, integrating quantitative data from questionnaires (e.g., disposal practices, population demographics) with qualitative insights gleaned from in-depth interviews with key stakeholders (e.g., municipal officials, hospital supervisors, industrial representatives). This triangulation of data sources provides a more robust and nuanced understanding of the complex waste management landscape than either method could achieve independently.

2. Representative Sampling: The application of a stratified sampling technique for questionnaire administration across the four main towns (Buea, Mutengene, Tiko, Limbe) ensured that the sampled population was proportionally representative of the overall demographic distribution in Fako Division. With 352 questionnaires administered, a substantial dataset was collected from the household level.

3. Diverse Stakeholder Engagement: The study's inclusion of interviews with a wide array of stakeholders, including municipal authorities, HYSACAM officials [30], and representatives from hospitals and industrial zones, provides a holistic perspective on waste generation, collection, and disposal from institutional and operational standpoints. This engagement offers valuable insights into policy, practices, and challenges from those directly involved.

4. Use of Multiple Data Sources: Beyond primary data, the integration of secondary data from reputable sources such as BUCREP (population statistics) [31], HYSACAM (waste collection quantities) [30], and records from hospitals and the Ombe Industrial Zone enriches the study's empirical foundation and contextual depth.

5. Relevance and Timeliness: The study addresses a highly pressing and relevant issue, as evidenced by the rapid urbanization and associated waste management challenges in Fako Division [2, 7, 11, 31]. The updated evidence on the functionality of solid waste disposal systems is crucial for informing current policy and practice.

Limitations:

1. Self-Reported Data: A significant portion of the primary data relies on self-reported information from questionnaires and interviews. While efforts were made to ensure accuracy (e.g., direct interviews for illiterate respondents), self-reported data can be subject to recall bias, social desirability bias, or a lack of precise knowledge regarding waste quantities or specific disposal methods.

2. Scope of "Effects" Analysis: While the study investigates the "effects of waste disposal systems," the depth of analysis regarding environmental and health impacts appears to be largely descriptive, relying on observed conditions and stakeholder perceptions. Without direct environmental sampling (e.g., water quality testing, soil analysis for leachate contamination [17, 32, 36, 38]) or epidemiological studies [4, 34, 40], the study can only infer the extent of contamination and health hazards, rather than quantify them directly.

3. Generalizability of Industrial Waste Treatment: The statement that industrial wastes are "thoroughly treated before discharge into the sea" is based on self-reporting from industries. The study does not present independent verification or detailed analyses of these treatment processes, which limits the ability to conclusively assess their environmental efficacy [23, 24, 25, 41].

4. Limited Specificity on Disposal Facilities: While the study identifies types of disposal (open dumpsites, unsanitary landfills, pits, culverts, rivers), it lacks granular detail on the precise operational specifics of these sites (e.g., volume, age, liner presence for landfills, specific components of incinerators). This limits a deeper engineering or environmental assessment [17, 23, 32, 33, 35].

5. Absence of Economic Analysis: The study does not delve into the economic dimensions of waste management, such as the cost-effectiveness of current systems, funding mechanisms for HYSACAM or municipal services, or the economic viability of alternative solutions. Financial constraints are often a major barrier in developing countries [3, 19], and their exclusion limits the comprehensiveness of proposed solutions.

6. No Direct Community Engagement in Solution Design: While public sensitization is recommended, the study does not detail processes for direct community engagement or co-design of waste management solutions, which could enhance adoption and sustainability [10, 22, 37].

Acknowledging these limitations is crucial for interpreting the study's findings and guiding future research efforts towards more in-depth analyses, particularly in quantifying environmental impacts and exploring economic and participatory aspects of waste management.

4.4. Implications for Theory and Practice

The findings of this study on solid waste disposal systems in Fako Division carry significant implications for both theoretical frameworks in waste management and practical interventions on the ground.

Theoretical Implications:

1. Reinforcing the Urbanization-Waste Nexus in Developing Contexts: This study emphatically reinforces existing theoretical constructs that link rapid urbanization directly to escalating waste generation and management challenges [2, 7, 11, 31]. It provides localized empirical evidence from Fako Division that substantiates global models depicting the strain on municipal services in fast-growing cities of developing countries [1, 19, 20, 35]. This adds to the growing body of literature emphasizing that urbanization, while offering development opportunities, also creates a high concentration of waste, demanding innovative and efficient MSW services [6, 19].

2. Critiquing Public-Private Partnerships (PPPs) in Waste Management: The study's observations regarding HYSACAM [30], a public-private partnership responsible for waste management in Buea and Limbe, reveal a critical gap between policy intention and practical outcome. The continued prevalence of uncollected waste and the use of unsanitary landfills despite HYSACAM's involvement [36] suggest that PPPs, while theoretically promising for resource mobilization, require rigorous oversight, clear performance metrics, and adaptable operational models to be effective in dynamic urban environments with rapid population growth [3, 9, 19]. This challenges simplistic notions of PPPs as a panacea for waste management issues in developing nations.

3. Highlighting the Multifaceted Nature of "Informal" Disposal: The study unpacks the various forms of informal waste disposal—open dumpsites, direct disposal into water bodies, burning of plastics, and use of culverts [1, 19, 35, 36, 40, 41]. This provides a more granular understanding of "waste mismanagement" beyond a singular definition, emphasizing the diverse adaptive behaviors adopted by populations in the absence of formal, accessible, and affordable services. This nuanced understanding is critical for developing context-specific theoretical models of waste behavior and governance.

4. Emphasizing Environmental and Health Externalities: The clear demonstration of environmental contamination (water, soil, air) [17, 23, 24, 25, 28, 32, 33, 34, 35, 36, 38, 40, 41] and associated health risks (disease vectors, odors, flooding) [4, 34, 35, 40] directly attributable to current disposal practices underscores the critical importance of integrating environmental and public health impact assessments into waste management planning theories. It highlights the significant externalities of inadequate waste management, often borne disproportionately by vulnerable communities.

Practical Implications:

1. Urgent Need for Integrated Waste Management Systems: Fako Division urgently requires a shift from fragmented and informal practices to an integrated waste management system that encompasses collection, transport, treatment, and environmentally sound disposal. This means expanding the reach of formal collection services to areas currently unserved by HYSACAM [30] and investing in proper sanitary landfills that adhere to engineering and environmental standards [15, 26, 27].

2. Infrastructure Development and Upgrade: The existence of "poorly designed unsanitary landfills" demands immediate attention. Investment in upgrading existing facilities to sanitary landfills, with proper liners, leachate collection and treatment systems [17, 23, 32], and gas recovery mechanisms, is paramount to mitigate environmental pollution [26, 27]. The absence of a system in Tiko necessitates the establishment of basic collection and disposal infrastructure.

3. Public Awareness and Behavioral Change Campaigns: The widespread practice of disposing of waste in pits, culverts, and water bodies underscores a critical need for sustained public sensitization campaigns. These campaigns should not only highlight the health and environmental hazards of improper disposal but also educate communities on proper waste separation at source [10, 13], responsible disposal methods, and the available formal services. Community involvement and participation are essential for long-term success [1, 10, 22].

4. Strengthening Regulatory Oversight and Enforcement: The reported "thorough treatment" of industrial waste needs to be verified through independent monitoring and strict regulatory enforcement. Clear guidelines and penalties for non-compliance are necessary to ensure industries adhere to environmental protection standards, particularly concerning discharges into sensitive marine environments [22, 24, 25, 41]. Similarly, regulations against open dumping and burning need rigorous enforcement.

5. Capacity Building for Municipalities: The challenges faced by local authorities due to lack of organization and financial resources highlight the need for capacity building initiatives [19]. This includes training for municipal staff in waste management planning, operational efficiency, and financial management, as well as exploring sustainable funding models for waste services [3].

6. Exploration of Waste-to-Resource Opportunities: While not explicitly detailed, the varied composition of waste, including organics and recyclables [14, 29], suggests potential for resource recovery initiatives [6, 26]. Practical interventions could explore composting of organic waste (as suggested by Folefack, 2008) [37] or establishing recycling programs for plastics and other recyclables [10, 41] to reduce the volume of waste requiring disposal and potentially generate economic value.

In sum, the study provides a robust empirical foundation for both refining theoretical models of urban waste management in developing countries and guiding actionable, context-specific interventions in Fako Division to address its pressing solid waste crisis.

4.5. Conclusion and Future Research Directions

The comprehensive investigation into solid waste disposal systems in Fako Division, South West Region of Cameroon, clearly demonstrates that rapid urbanization and population growth [2, 7, 11, 31] have overwhelmed existing waste management infrastructure and practices. The study concludes that the predominant methods of waste disposal, including widespread open dumpsites, direct discharge into water bodies (rivers, streams, culverts), and burning of non-biodegradable materials, pose severe and immediate threats to both environmental quality and public health [4, 17, 19, 23, 24, 25, 28, 32, 34, 35, 36, 38, 40, 41]. While formal entities like HYSACAM are operational in some areas [30], their services are often insufficient in coverage, and the reliance on unsanitary landfills indicates a significant gap in environmentally sound disposal practices [19, 35]. The complete absence of a structured waste management system in certain municipalities, such as Tiko, further exacerbates the problem, leading to unregulated and hazardous disposal behaviors. Hospital waste, while managed on-site with incineration, requires further scrutiny regarding environmental controls, and industrial waste treatment claims need independent verification to ensure marine protection [23, 24, 25, 41].

In light of these findings, it is imperative for Fako Division to transition towards a truly integrated and sustainable solid waste management system. Key recommendations include:

- Investment in Modern Infrastructure: Developing and upgrading to properly engineered sanitary landfills with leachate collection and treatment systems [15, 17, 23, 26, 27, 32] is crucial for environmentally safe disposal.

- Expansion of Collection Services: HYSACAM [30] and municipal authorities must expand their collection services to cover all residential, commercial, and industrial areas, reducing the incentive for indiscriminate dumping.

- Intensified Public Awareness Campaigns: Continuous and targeted public sensitization programs are essential to educate residents on the dangers of improper waste disposal and promote waste segregation at source [10, 13] and responsible practices. Community involvement and participation are essential for long-term success [1, 10, 22].

- Strengthened Regulatory Framework and Enforcement: Robust environmental regulations and their strict enforcement are necessary for industries, hospitals, and households to ensure compliance with safe disposal practices [18, 22].

- Exploration of Resource Recovery: Investigations into composting organic waste (as suggested by Folefack, 2008) [37] and establishing formal recycling programs for recyclables [6, 10, 26, 41] could reduce landfill burden and generate economic value.

Future Research Directions:

This study provides a foundational understanding, but several avenues for future research emerge to build upon these findings and provide more granular insights:

1. Quantitative Assessment of Environmental Contamination: Future research should conduct direct environmental sampling (e.g., water quality analysis of rivers and boreholes near dumpsites [36, 38], soil contamination studies around landfills [17, 32]) to quantify the precise levels and types of pollutants emanating from waste disposal sites. This would provide empirical evidence of the environmental health risks.

2. Public Health Impact Assessment: Longitudinal epidemiological studies could investigate the direct links between proximity to informal dumpsites/polluted water bodies and the prevalence of specific diseases (e.g., waterborne diseases [34], respiratory illnesses from open burning) among affected populations [4, 40].

3. Economic Feasibility and Cost-Benefit Analysis: A detailed economic analysis of current waste management costs versus the investment required for improved systems, including potential revenue from recycling and waste-to-energy initiatives, would be invaluable for policy-makers.

4. Behavioral Studies on Waste Segregation and Recycling: In-depth qualitative and quantitative studies could explore the socio-cultural factors, knowledge gaps, and economic incentives that influence household waste segregation and recycling behaviors [10, 22, 37], informing more effective intervention strategies.

5. Comparative Analysis of Waste Management Models: A comparative study of successful waste management models in similar rapidly urbanizing regions of other developing countries could offer transferable lessons and best practices for Fako Division [5, 15, 16, 21].

6. Detailed Assessment of Industrial and Hospital Waste Treatment: Independent audits and detailed analyses of the treatment technologies and effectiveness of industrial wastewater and hospital waste incineration processes are needed to verify environmental compliance and identify areas for improvement [23, 24, 25, 41].

7. Participatory Action Research for Community-Led Solutions: Future studies could engage in participatory action research to co-design and implement community-led waste management solutions, leveraging local knowledge and fostering ownership [1, 6, 10, 22, 37].

By pursuing these research directions, Fako Division, and indeed other regions facing similar challenges, can move closer to achieving sustainable and environmentally responsible solid waste management.

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