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Assessment of Integrated Solid Waste Management Practices in Debrebrehan Reogiopolitant City: The Case of Menelik sub-city, Ethiopia

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Abstract

The issue of solid waste has emerged as a significant urban challenge in numerous countries today. In earlier times, when populations were smaller and technological progress was limited, solid waste management did not pose substantial difficulties and received comparatively little attention. In this study, an assessment of municipal solid waste management (MSWM) practice was conducted in Menelik sub-city of Debrebrehan, Amhara region, Ethiopia. This study employed a descriptive research framework, utilizing multiple data collection strategies, including questionnaires, interviews, focus group discussions, and observational methods. A total of 318 household respondents were systematically sampled from eight kebeles (the smallest administrative structure of the country). Analysis of waste generation rates reveals that individuals classified within low-income generated an average of 0.31 kg/cap/day whereas middle-income individuals produced an average of 0.49 kg/cap/day. High-income individuals produced an average of 0.67 kg/cap/day, which is more than twice the waste produced by those in the low-income category. The analysis displayed that composition of municipal solid waste (MSW) in the sub-city was predominantly organic (60%), with recyclable materials accounting for 15% and other waste types comprising 25%. The result of the study showed that rapid population growth, low technology, poor community participation, improper SW disposal, lack of public awareness, economic constraints/financial issues as a dominant driving factor for inefficient SWM. The findings of the study highlighted that strengthening governance, increasing financial outlay, fostering community participation, and implementing targeted public awareness campaigns are critical to ensuring sustainable and efficient waste management systems in the study area and beyond.

Key words: *Integrated solid waste management; Menelik sub city, Transportation; Waste Generation, Waste Storage and Disposal*

1 INTRODUCTION

Municipal solid waste management is a key environmental concern in most countries worldwide. The rapid pace of urbanization in these areas has resulted in waste generation outstripping the capacity to collect, transport, dispose of, and manage its impact [1]. Studies forecast that by 2050, global waste production will rise by 70%[2, 3]. Waste management in any nation is influenced by its economic, social, and political conditions[4, 5]. Integrated Solid Waste Management (ISWM) is a holistic approach that focuses on recycling, composting, and disposal methods to establish an effective waste management system [6, 7]. Developing countries spend about $46 billion every year on municipal solid waste management [8, 9]. By 2025, investments in municipal solid waste management could exceed $150 billion. However, due to factors like poor planning, weak governance, limited technology, ineffective enforcement of regulations, and the lack of economic incentives, ISWM continues to be inefficient in many countries, including Ethiopia [10].

Limited financial resources, technical expertise, and effective solid waste management planning are prevalent. Additionally, the public's negative attitude toward proper collection and sorting systems is contributing to the growing environmental and health challenges in cities of developing countries [11]. Managing solid waste is a significant public health and environmental issue in many African cities [12]. The generation and disposal of waste can have damaging impacts on animals, plants, ecosystems, and the overall environment[1]. Effective waste management is essential to minimize environmental harm and recover valuable resources[13, 14]. In Ethiopia, municipalities have mainly been responsible for ISWM

services. However, their effectiveness is limited due to insufficient waste collection, inadequate sanitary facilities, and poor planning and coordination[11]. However, there has been a notable shift, with solid waste now being actively collected, disposed of, or processed for future use[11]. Achieving sustainable and environmentally responsible waste management requires a holistic approach that integrates social, cultural, economic, and ecological factors [15]. Urbanization, combined with poor waste management practices such as the careless disposal of waste into water bodies, littering along roadsides, and the presence of unmanaged dumpsites, worsens sanitation problems in several African countries, including Ethiopia [16]. Africa is experiencing rapid population growth and urbanization, both of which are progressing at an alarming rate. Unfortunately, the continent faces considerable challenges, including a lack of technology, technical expertise, financial resources, community engagement, and awareness, all of which are vital for effective solid waste management[17, 18]. Effective waste management strategies are crucial for economic development, particularly in developing nations [17, 18]. Lack of knowledge, coupled with financial and technological limitations, has contributed to the poor management of solid waste [18, 19]. Ethiopia, a large amount of solid waste remains unmanaged, which has significantly affected both public health and the environment [18, 20].

A preliminary assessment conducted by the researcher in October 2024 found that household solid waste in Debrebrehan Reogiopolitant City is often left on the streets, burned in villages, or improperly dumped into the sewer system. As a result, Debrebrehan Reogiopolitant City, like many other cities in developing countries, faces challenges that prevent authorities from managing waste efficiently, cost-effectively, and sustainably. Despite increasing involvement from various stakeholders in waste management and improved legal frameworks, the solid waste issue in Debrebrehan Reogiopolitant City continues to worsen. Menelik Sub-City is characterized by unplanned settlements, high population density, and congestion, which is believed to generate substantial amounts of solid waste, potentially causing public health and environmental problems. Hence, this paper seeks to explore and identify the challenges related to solid waste management in Menelik Sub-City.

2. Materials and methods

2.1 Noticeable features of the study area

For this investigation, the researcher specifically selected Menelik Sub-City as the focus area due to its dense population and congested environment, which provide a more thorough understanding of the solid waste management challenges. Additionally, the researcher is more familiar with this sub-city. The research is based on data gathered from September 1, 2024, to October 13, 2024. The city is positioned at 9°41' North latitude and 39°40' East longitude as indicated in Figure 1. Debre Berhan City was founded in 1454 under the reign of Emperor Zera Yaeqob [21]. It is located in the Amhara National Regional State and serves as the administrative hub for the Northern Shoa Zone, Debre Berhan City Administration, and Bassona Worana Woreda (district). Geographically, the city is about 130 kilometers northeast along the Addis Ababa–Dessie-Mekelle route[22]. The annual precipitation in the region varies between 814 and 1080 mm. Most of Debre Berhan City's urban areas are situated at an altitude of 2750 meters above sea level. The city's landscape is mostly flat, covering 86% of the land, with slopes occupying 10% and mountainous areas making up the remaining 4%. Debre Berhan spans a total area of 21,169.95 hectares. The local economy is mainly driven by tanneries and blanket production, while agriculture in the surrounding suburbs supports a large portion of the local population's livelihoods[22].

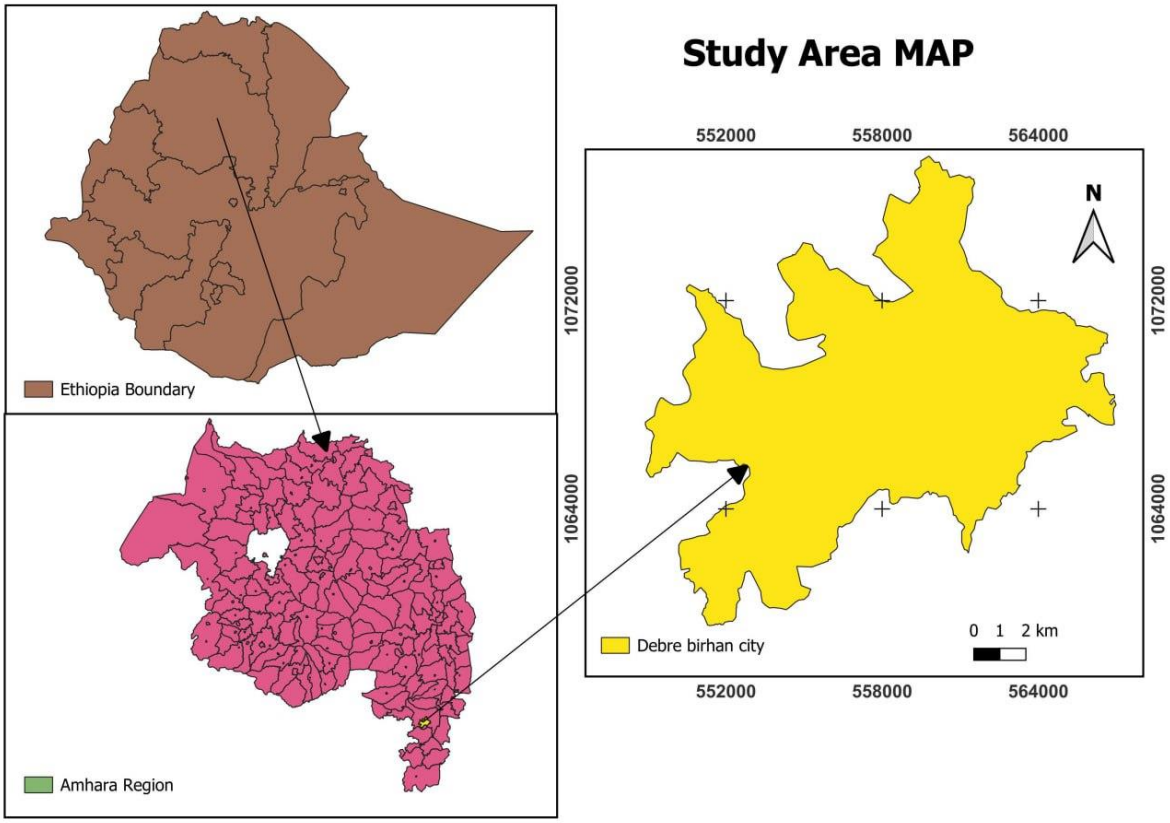

Fig -1: Maps of study area

Agriculture is the main economic activity in Debre Berhane, with most of the population involved in subsistence farming. Livestock farming is a key component of the agricultural system, with cattle, sheep, and goats being the most commonly raised animals, providing meat, milk, and other products. Poultry farming, especially chickens, is also widespread, contributing to local diets and income. Livestock serves as a form of wealth, used in traditional ceremonies and as a means of exchange. According to recent estimates, Debre Berhane's population stands at approximately 250,384 (Central Statistical Agency of Ethiopia, 2023), with the majority living in rural areas and a smaller proportion in urban areas. The population of Debre Berhane is largely young, with a significant proportion under the age of 30. The city's economy is primarily agricultural, with most people depending on farming for their livelihood. There are also small-scale industries, such as handicrafts, pottery, and weaving, that help supplement local incomes. Like many rural areas in Ethiopia, Debre Berhane faces challenges in infrastructure, education, and healthcare. Despite these obstacles, the region holds considerable potential for development. The area is prone to occasional droughts, especially during the dry season, which can affect crop yields and threaten the livelihoods of farming families. Additionally, limited access to modern farming technology and poor road infrastructure hinders economic growth and market access.

2.2 Approaches of data collection and analysis

To achieve the specific goal of this study, both primary and secondary data sources were used. Primary data was collected through field observations and interviews with a sample of residents, cooperative partnership associations, and sanitation administration employees. Secondary data was obtained from various sources, including both published and unpublished documents from the sanitation administration office, the finance and economic development office, and the sub-city administration. Similar methods, such as semi-structured interviews, were also used by other researchers to gather public opinion. The study employed both open and closed-ended questions to extract valuable information. Respondents were selected using a systematic selection technique from residents, cooperative partnership associations, and sanitation administration staff. Household respondents were further selected through systematic random sampling, as described by

Wubie, Assen and Nicolau [23]. From three elevation categories: Lower (500–1800 m a.s.l. which include Selam Chora, Loretafework Tekile, and Eyerusalem *kebeles*), Middle (1801–2400 m a.s.l. consisting of Fitwurari Gebeyehu and Nigist Eleni *Kebeles*), and Upper (2401–2800 m a.s.l. covers Woshawushgn, Anisessmariyam, and Dilila *kebeles*), 106 households from each segment were chosen for the socioeconomic analysis. The socioeconomic study was carried out in two main stages. First, sample sites were selected. Then, households within the chosen kebeles, the smallest administrative units in Ethiopia, were identified. Systematic random sampling, as outlined in established methodologies[24], was used to facilitate this process. The sample size for the study area was determined using the methodology outlined in a previous research conducted by Cochran [25], as outlined in Eqs 1and 2.

$$n = \frac{n_o}{1+\frac{n_o}{N}} \quad \text{..... (1)}$$

$$\text{Where; } n_o = \frac{Z^2 p(1-p)}{e^2} \quad \text{..... (2)}$$

In the provided formula, n_o = the desired sample size when the population is > 10,000 whereas n = sample size when the population is <10,000. While 'Z' signifies the 95 percent confidence limit or interval on the normal distribution curve, which is equivalent to 1.96. Additionally, 'P' corresponds to the proportion of the population to be included in the sample, set at 0.1. '1' denotes a unit or constant, q = 1–0.1 i.e. (0.9). 'N' stands for the total population, and 'e' represents the permissible amount of sampling error, set at 0.05. Assuming the city population size was around 250,348 and the number of households was estimated to be 66,529 based on the projection of Ethiopian Statistical Agency, 2007, and a confidence level of 95% and with a margin of error (0.05), a sample size of 318 was calculated for household respondents as indicated in Table 1. To get the calculated sample size response 318 questioners were administered in two languages namely English and Amharic. Amharic languages are local languages that are dominant in the country.

Table -1: Sampling trend for sample size determination

Altitude	A. Ecology	HHs (No)	HHs (%)	Sample S (No)	Sample S (%)
500-1800	Lowlands	80,116	32	108	32.1
1801-2400	Midlands	83,116	33.2	100	33.3
2401-3200	Highlands	87,116	34.8	110	34.7
Total		250, 348	100	318	100

The presented Figure 2. provides a detailed visualization of the distribution of households (HHs) across three ecological zones Highlands, Midlands, and Lowlands classified by altitude ranges (500–1800 m, 1801–2400 m, and 2401–3200 m). The figure summarizes the total household numbers, their proportional representation, and the sampling strategy employed in the study. The Highlands, situated at the highest altitude range (2401–3200 m), exhibit the largest population of households, totaling 87,116, which accounts for 34.8% of the total household population. The Midlands, located at an intermediate altitude range (1801–2400 m), follow closely with 83,116 households, representing 33.2% of the total. The Lowlands, characterized by the lowest altitude range (500–1800 m), have the smallest number of households, totaling 80,116, contributing 32.0% to the overall population. The sampling strategy for this study is depicted alongside the total household data. From the total household population, 108 households were sampled from the Highlands, 100 from the Midlands, and 32 from the Lowlands. These values correspond to 34.7%, 33.3%, and 10% of the total sampled households, respectively. The sampling proportions closely align with the total household distribution in the Highlands and Midlands but exhibit a notable underrepresentation of the Lowlands. This discrepancy may indicate a strategic emphasis on higher altitude zones or methodological constraints that limited sampling in the Lowlands.

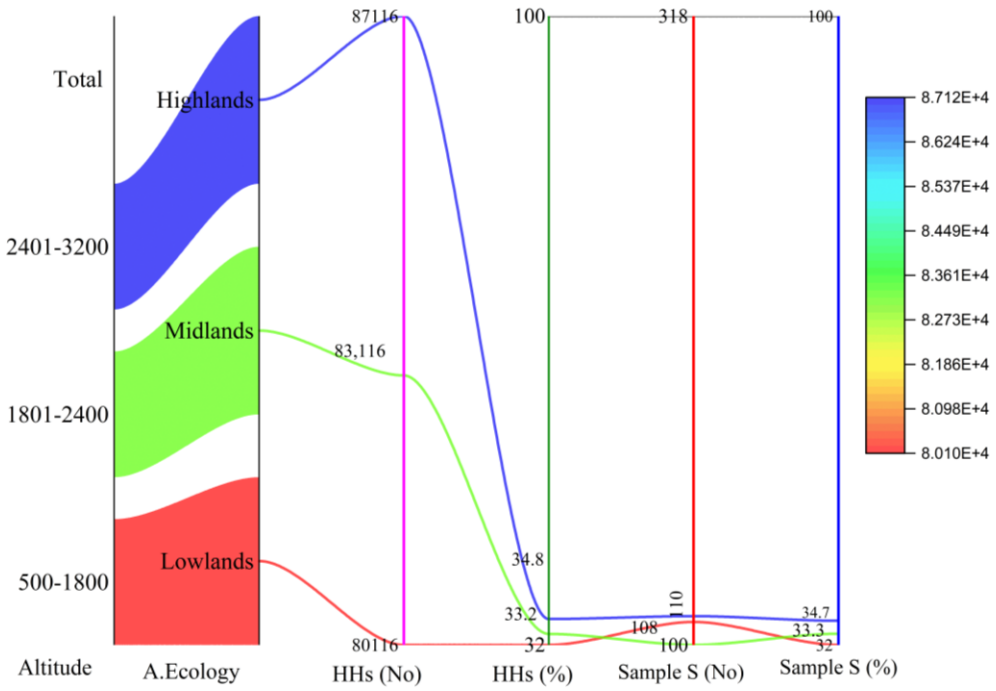

Fig -2: Sampling trend for sample size determination

2.3 Socio-economic data

Data for the study were collected using various data collection techniques, including rapid appraisal methods, key informant interviews, direct observation, in-depth interviews, and questionnaires. This allowed for the gathering of both qualitative and quantitative data, as outlined below. The questionnaires were initially created in English and then translated into Amharic to ensure clarity for the participants. Additionally, both structured and unstructured interviews, as well as uncontrolled observation, were utilized. Two types of questionnaires (open and closed-ended) were designed for residents, sanitation administration employees, and members of the cooperative partnership association. Structured and unstructured interviews were conducted with the head and workers of the sub-city sanitation administration, as well as with cooperative partnership associations, to gather information on the institutional setup, capacity, and challenges. Data for community and stakeholder studies were collected from both primary and secondary sources, including focus groups and household (HH) surveys. An initial reconnaissance survey was conducted to understand the study areas comprehensively. During this preliminary survey, discussions were held with various participants, including farmers and extension staff who interact closely with them [26]. This study used a guiding questionnaire and semi-structured household questionnaires to examine the different methods for MSW collection, storage, treatment, transportation and disposal. The questionnaire, which consisted of open and closed-ended questions, offered insights into these changes' drivers. Initially tested on 25 households in four districts or *Kebeles* (but not part of the primary study sample), it was modified and administered to four hundred two HHs from 8 *Kebeles*/districts between September 2024 and November 2024. A socioeconomic survey involving 318 randomly chosen households was executed. The district, administrative bodies, and household participants were carefully chosen using a three-stage sampling method that combined purposive and random approaches.

2.4 Focus group discussion and key informant interview

Focus group discussions utilizing semi-structured questions provide researchers with the opportunity to delve deeper into topics and explore new avenues of inquiry that may arise during interviews. In contrast to formal questionnaire interviews, group discussions offer a more conducive environment for addressing sensitive topics, as individuals may feel more comfortable discussing these issues within a group setting rather than one-on-one with a stranger. Additionally, two FGDs were

held, each with five participants, in total ten persons out of them four women and six men. These participants represented various groups, including development agents, *Kebeles* cabinet members, and public elders. These individuals were carefully chosen via the *Kebeles* administrative entities and informed public representatives. Through key informant interviews and FGDs, we have thoroughly understood the SWM and current solid waste status in the study area [27]. A careful selection process was employed to identify and engage ten individuals aged >50 chosen as key informants' interviews (KIIs) to facilitate a rigorous investigation. Skilled personnel were enlisted to offer assistance in the interview process. The assistants were educated professionals who spoke the regional and local languages. Different training activities were carried out for the assistants, covering topics like how to make contact, conduct interviews properly, and cultural considerations. The early morning and late afternoon, normally ideal periods for KIIs, were used to interview individual households. These were the best times of the day for households because neither agricultural work nor any other household-related activities took place then. If the informant refused to provide information, they were asked to recommend someone open to acting as an informant. Additionally, the discussion also addressed the matter of the most pressing solid waste issues that demand intervention. Throughout the conference and the interviews, the primary focus remained finding solutions to these problems [28].

This multi-method approach facilitated a robust analysis, providing a clear and comprehensive picture of the challenges faced and potential solutions to address SWM problem in the region. In addition to personal life experiences, a field tour of selected areas of the city was conducted. The primary areas of focus included: 1) solid waste disposal sites located in Menelik sub-city; and 2) the road sides and ditches of the sample *Kebele*. This observation and experience gained from simply being a member of the community aided in the evaluation of research questions and objectives. In addition to these, the researcher used field observation as a data collection tool for this study. Field observation was also used to assess the spatial distribution of the sub city's solid waste management infrastructures, illegal dumping, solid waste collection and transportation systems, and disposal site facilities. In order to make the questionnaire that was adopted in English more intelligible to responders, it was translated into Afan oromo and Amharic. Third, ten respondents who were not involved in the data collection process were given the questionnaire as part of a pilot test to assess its reliability and validity. Based on the results of the pilot test, changes were made to the questionnaire. Finally, using temporary data enumerates, actual data gathering was completed. Data enumerators have obtained the necessary training and speak Amharic with ease.

2.5 Methods of data analysis

The presentation, analysis, and interpretation of data gathered from homes, the Menelik sub-city office, and field research are the topics of this part. Both qualitative and quantitative techniques were used to analyze the data. Open ended questions and interviews received qualitative responses, whereas closed-ended questions were given quantitative responses. Examples of percentages, tabular analysis, and frequency distribution quantitative methods. Among the qualitative methods employed were links between causes and effects and inductive and deductive reasoning. Using the computer program SPSS version 28, Origin pro-25, questionnaires were analyzed using quantitative techniques, i.e. tables, which were frequently utilized to illustrate the acquired data. Using descriptive data analysis approaches, frequency, percentage, mean, standard deviation, and graphic representation were produced.

3. Results and Discussions

3.1 Composition of MSW in Menelik sub-city

The composition of municipal solid waste (MSW) in Menelik Sub-city appears to be relatively low. Various factors, such as the type of waste source (household, commercial, etc.), the level of income, seasonal changes, and other influences, significantly impact the composition of solid waste. As a result, the actual waste makeup may differ from what is depicted in Table 2 below, especially as the waste stream from plastic bags has sharply increased in recent years. According to the Menelik Sub-cities Report of 2024, the waste management (SWM) data shows that 60% of the total waste is organic, while 15% consists of recyclable materials, and the remaining 25% falls into other categories. This indicates that the daily and annual composition of waste may vary, influencing the community in different ways. The most significant component of the waste stream comprising 65.8% was found to be ash, dust, and fines. This large proportion suggests that industrial activities, construction projects, and combustion processes contribute substantially to waste generation. Organic waste, which is mainly fruits and vegetables, made up 15.2%, pointing to a notable amount of food waste coming from households, markets, or food processing sectors.

Table -2: Composition of MSW types in Menelik Sub-city

No	Major constituents	percentage
1	Ash, dust, fines	65%
2	Combustible leaves and grasses	15%
3	Vegetables and fruits	4.20%
4	Rubber and plastics	2.90%
5	Non-combustibles	2.50%
6	Papers	2.50%
7	Textiles	2.40%
8	Wood	2.30%
9	Bones	1.10%
10	Metals	0.90%
11	Glasses and ceramics	0.50%

3.2 Municipal solid waste and its handling

Figure 3 presents a detailed breakdown of survey responses regarding the effectiveness of trained key informants (KIIs) in managing solid waste (SW). The responses are divided into three categories: "Yes," "No," and "Total," with the corresponding number of respondents and percentages. In the "Yes" category, 140 respondents (44% of the total) indicated that they believe trained KIIs are effective in waste management. While this shows moderate confidence in KIIs' ability to handle waste management tasks, it doesn't represent a majority opinion. This finding is comparable to other studies, such as [29], which reported affirmative responses ranging between 50-60% in urban settings where structured training programs for waste management professionals were implemented. The slightly lower percentage could point to contextual or systemic differences in how these programs are implemented and perceived. In the "No" category, 177 respondents (55.7% of the total) expressed skepticism or dissatisfaction, indicating that the majority of people do not view trained KIIs as effective in managing solid waste. The higher proportion of negative responses aligns with studies like [30], where similar surveys reported 56-62% negative feedback in regions with inconsistent waste management practices or limited public engagement. This suggests that factors like inadequate training, operational inefficiencies, or a lack of awareness may reduce the perceived effectiveness of trained KIIs. With a total of 318 responses, the dataset is sufficiently large to support statistical analysis and comparisons. The consistency in the total values across both numerical and percentage axes further ensures the reliability and accuracy of the data for cross-study comparisons.

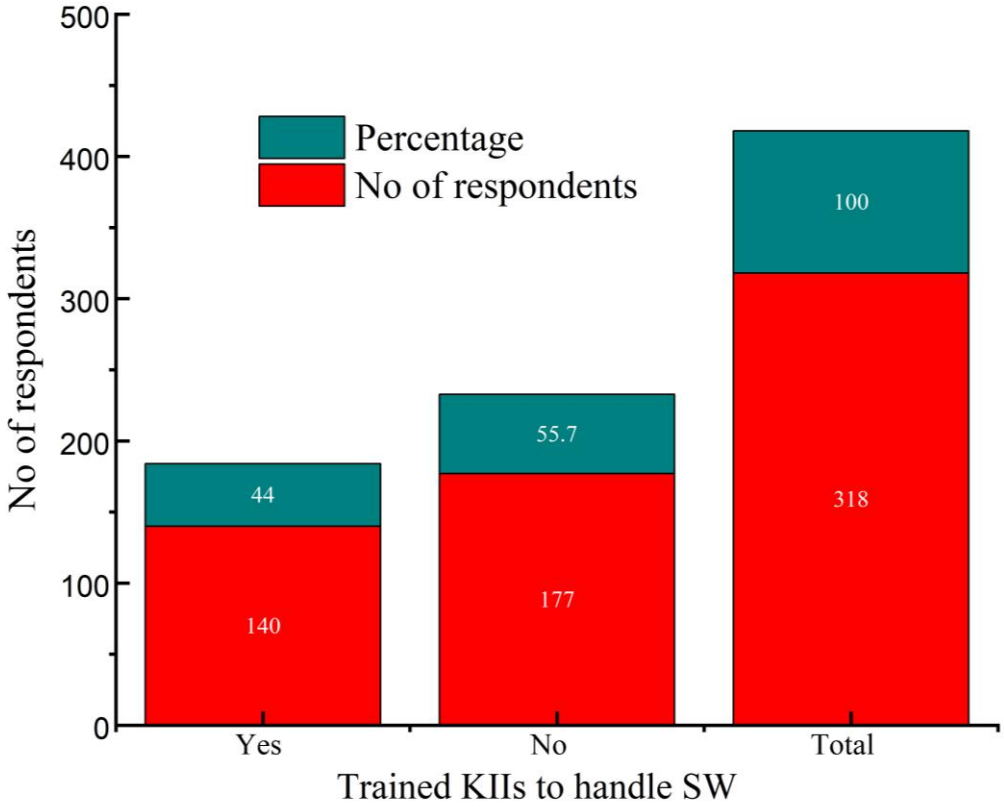

Fig -3: Solid Waste and its adequately handling

The results of this study reveal a clear predominance of negative perceptions (55.7%), aligning with findings from similar studies. For instance: Smith, Jones and Taylor [29] found that in urban areas with well-structured training programs and consistent waste management policies, positive feedback typically ranged from 50-60%. This indicates that public confidence is strongly linked to tangible and visible outcomes. In contrast, the 44% of positive responses in the current study point to potential gaps in how the roles of KIIs are implemented or perceived. Studies carried out by Green, Jones and Taylor [31] emphasized the role of trust in waste management systems, finding that in areas where public engagement campaigns were absent, "No" responses constituted 60% or more of the total. The findings of the current study are in line with this, suggesting that limited public awareness and communication may be contributing factors. Previous studies have consistently highlighted the critical role of training in enhancing the effectiveness of waste management professionals: Studies by Taylor, Zhang and Li [32] discovered that structured, continuous training programs for KIIs led to better public perceptions, reducing negative responses to an average of 40%. The absence of such comprehensive training programs may help explain the higher number of "No" responses observed in this study. Similarly, Jones, Lee and White [33] noted that in regions where training focused on both technical skills and community engagement, affirmative responses increased by 20-30%. The current findings, with only 44% of responses being positive, suggest that there may be shortcomings in the training programs or the way they are delivered to key informants (KIs). Operational inefficiencies have also been identified as a significant barrier to public trust in waste management systems: Brown and Taylor [30] reported that areas with delayed waste collection or visible inefficiencies experienced "No" responses as high as 62%, reflecting public frustration.

3.3 Households' SW and distribution of responsibility for disposing

Figure 4 illustrates how responsibility for solid waste (SW) disposal is distributed among various individuals or groups within households: house servants, children, household heads, hired small-scale employees, and other individuals. The chart uses dual y-axes to show the frequency of responses on the left and the corresponding percentages on the right, providing a comprehensive view of the data. House servants were responsible for waste disposal in 102 households, making up 32.1% of

the responses. This suggests a strong reliance on domestic help, likely influenced by socioeconomic factors and cultural norms that encourage outsourcing household chores. Additionally, 43 households (13.5%) assigned waste disposal to children, which, while a smaller proportion, indicates that some families involve younger members in routine household tasks. The largest share of responsibility, 130 households (40.9%), was attributed to household heads. This suggests that, in many families, the head of the household assumes direct responsibility for waste management, potentially due to cultural expectations, the lack of external help, or an emphasis on hygiene. On the other hand, 41 households (12.9%) hired small-scale workers specifically for waste disposal, indicating that some families invest in external assistance due to time or labor constraints. A small percentage (2.5%) of households relied on other individuals, which reflects unique or context-specific arrangements. The overall responses totaled 318, providing a solid dataset for comparison and analysis. The findings show varied practices in assigning responsibility for waste disposal. The dominance of household heads (40.9%) suggests that many families prefer self-management, possibly due to the lack of affordable domestic help or cultural norms. The reliance on house servants (32.1%) highlights the influence of socioeconomic factors on waste disposal practices. Meanwhile, the lower proportions for children (13.5%) and hired small-scale employees (12.9%) reflect demographic and logistical challenges in delegating this responsibility.

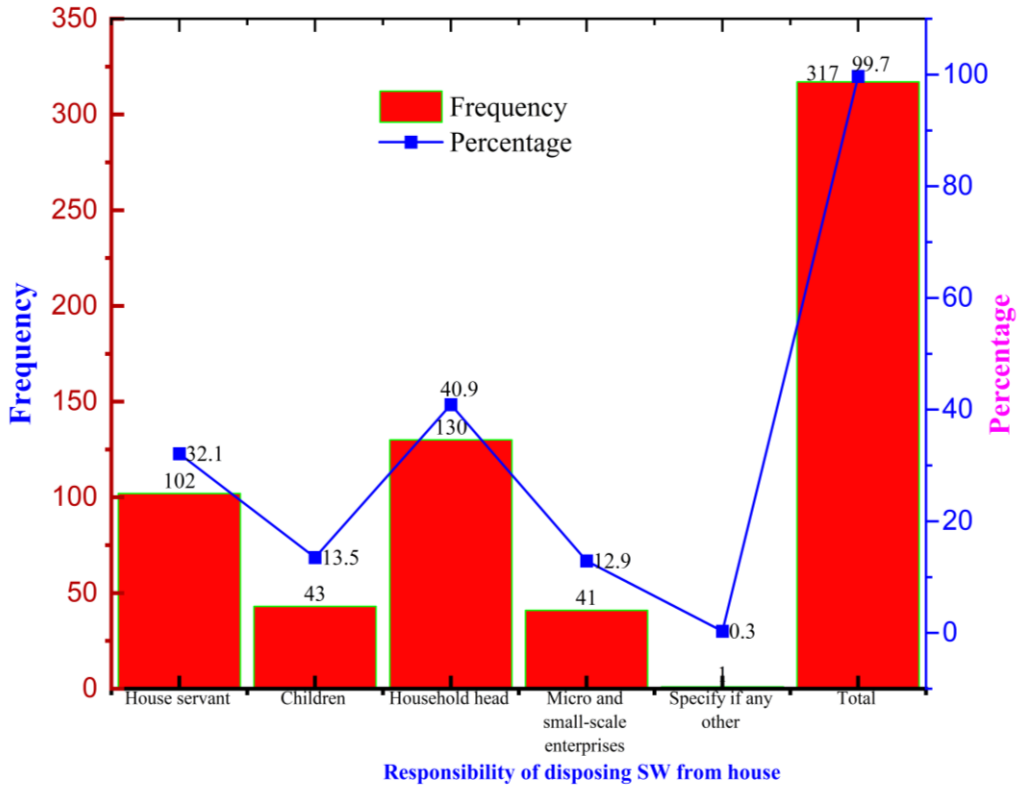

Fig -4: Municipal SW and its disposal responsibilities

The 40.9% of households that assign waste disposal responsibility to household heads is consistent with the findings of Green, Jones and Taylor [31], who observed a similar pattern in areas with limited access to municipal waste collection services. Their research suggested that in semi-urban and rural areas, household heads often take on this responsibility due to a lack of affordable alternatives. Their findings showed that in semi-urban and rural areas, household heads often take on responsibility due to the lack of affordable alternatives. In contrast, Smith, Jones and Taylor [29] found that in urban areas with well-established waste collection systems, only 25-30% of households relied on household heads for waste disposal. Instead, a larger portion of households delegated this responsibility to domestic workers or external service providers.

3.4 Solid waste generation rate in the study area

Figure 5 presents the solid waste generation rate (SWGR) categorized by income levels: low income, middle income, and high income. The data is provided in two dimensions: the average SWGR per household per day (Kg/HH/D) and per capita per day (Kg/Cap/D). A clear trend emerged showing that both household and per capita waste generation rates increased with higher income levels, indicating a positive correlation between income and waste generation. Low-income households had the lowest average waste generation rate at 1.45 Kg/HH/D. Middle-income households produced slightly more, averaging 1.85 Kg/HH/D, while high-income households had the highest production, reaching 2.41 Kg/HH/D. This suggests that high-income households produced nearly 66% more waste than low-income ones, likely due to differences in consumption habits and access to consumer goods and disposable products. On a per capita basis, the trend mirrored the household-level data, with low-income individuals generating the least waste at 0.31 Kg/Cap/D. Middle-income individuals produced 0.49 Kg/Cap/D, a 58% increase compared to the low-income group. High-income individuals produced the most waste, averaging 0.67 Kg/Cap/D, more than double the number of low-income individuals. This upward trend reflects a broader pattern of increased resource consumption and waste production as disposable income rises.

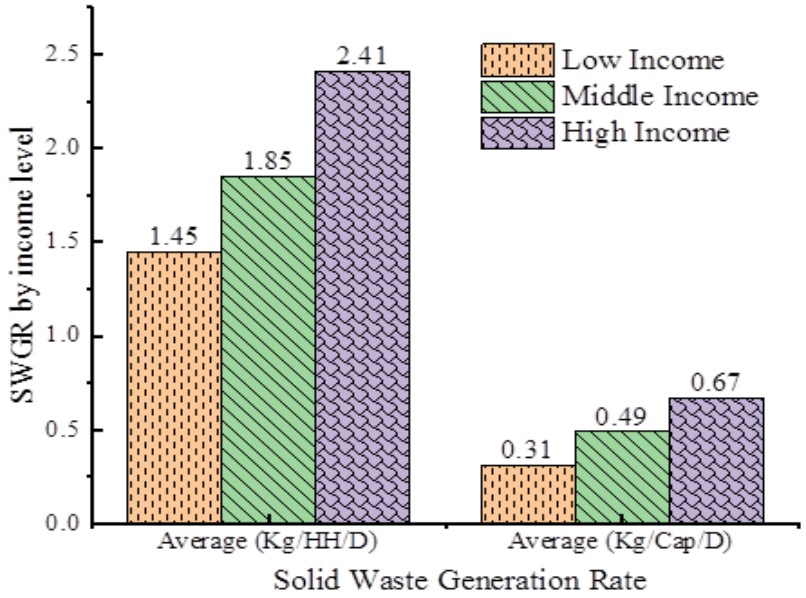

Fig -5: Municipal Solid Waste Generation Rate

The differences in waste generation across income groups can be linked to variations in consumption patterns, economic capabilities, and lifestyle choices. High-income households tend to consume more packaged and processed goods, resulting in higher levels of plastic, paper, and food waste. Their frequent use of disposable items further contributes to the increased waste. On the other hand, low-income households are more inclined to reuse materials, limit purchases to necessities, and avoid excessive packaging, which helps reduce their overall waste production. Middle-income households generated waste at rates that fell between those of the low- and high-income groups.

3.5 Major constraints that hinder effective solid waste management in the study area

3.5.1 Economic constraints/financial issues

The results showed that a majority of respondents, 148 out of 318 (46.5%), "highly agreed" that economic conditions and financial issues were major factors contributing to inefficient solid waste management (SWM) in the study area. Additionally, 61 respondents (19.2%) "agreed" with this statement, bringing the total agreement level to 65.7%, as shown in Figure 6. These findings emphasize the significant role that financial constraints play in the inefficiency of SWM systems, especially in regions

where limited funding, inadequate resources, and economic instability hinder the implementation and upkeep of effective waste management practices. Similar findings were reported by Ahmed and Ali [34], who highlighted that limited municipal budgets and high costs associated with waste collection and disposal were major barriers to achieving efficient SWM in developing countries. A smaller proportion of respondents, 41 individuals (12.9%), rated their agreement as "moderate," indicating a recognition of financial issues as a contributing factor but with less emphasis compared to those who strongly agreed. This response suggested that while economic conditions were seen as a significant challenge, other factors such as institutional inefficiencies, lack of public participation, or technical barriers may have also been perceived as contributing to the inefficiency of SWM systems. Other studies carried out by Smith, Jones and Taylor [29] emphasized that while financial challenges are often a primary driver of inefficiency, they are typically intertwined with governance issues and operational shortcomings.

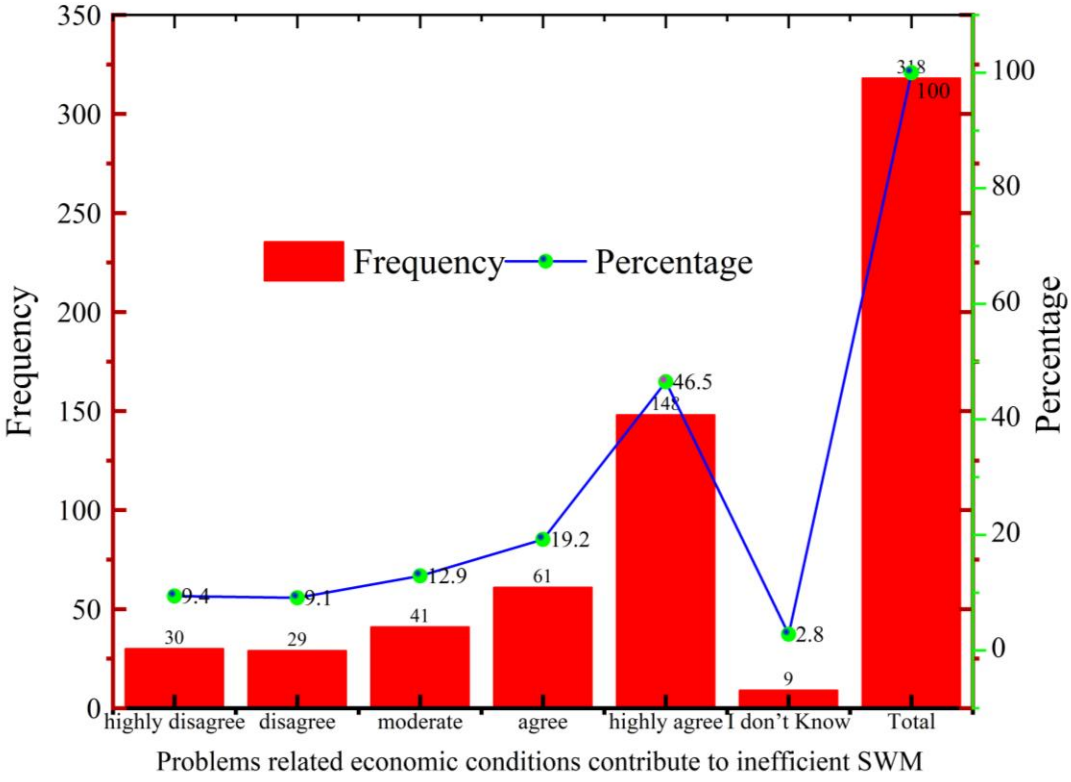

Fig -6: Economic conditions/financial issues contribute to inefficient SWM

Interestingly, 30 respondents (9.4%) "highly disagreed" and 29 respondents (9.1%) "disagreed" with the idea that financial issues contributed to inefficient SWM, making up 18.5% of the total responses. These individuals likely believed that other factors, such as poor planning, lack of public awareness, or systemic corruption, were more significant contributors to the inefficiency of SWM systems. Studies by Kumar and Gupta [35] found that in areas with poorly managed waste systems, public opinion often shifted blame away from financial problems, focusing instead on broader institutional failures, particularly when financial resources were perceived as being poorly allocated or mismanaged. A small group of respondents, 9 individuals (2.8%), selected "I don't know," indicating uncertainty or a lack of understanding regarding the financial aspects of SWM inefficiency. This could suggest that some participants were not fully aware of the link between economic conditions and waste management systems. This response may suggest that some participants lacked full awareness of the connection between economic conditions and waste management systems.[36] noted that public understanding of the financial underpinnings of SWM systems often depends on the level of transparency and communication provided by municipal authorities, which, if absent, can lead to uncertainty or apathy among residents. The high level of agreement (65.7%) indicated that financial constraints were widely perceived as a major obstacle to effective waste management.

3.5.2 Lack of awareness as a contributing factor to inefficient SWM

The analysis showed that a large majority of respondents recognized the role of a lack of awareness in contributing to inefficient solid waste management (SWM). Of the participants, 131 (41.2%) "highly agreed," and 101 (31.8%) "agreed," as shown in Table 3. Together, these responses made up 73% of the total, highlighting the widespread belief that low public awareness was a key factor in SWM inefficiency. These findings aligned with those of Chernet, Sema, Gebeyehu and Wogayehu [37], who reported that public awareness gaps regarding waste segregation, recycling, and proper disposal methods were major barriers to effective waste management in developing regions. A smaller group of respondents, 30 individuals (9.4%), gave a "moderate" rating, suggesting that while they acknowledged the importance of awareness, they may have also viewed other factors, such as financial or institutional issues, as equally important contributors to inefficiency. This perspective shows a more nuanced understanding of the complex challenges faced by SWM systems. emphasized that while lack of awareness is a significant barrier, it often interacts with other systemic issues, such as poor infrastructure and governance, to exacerbate inefficiencies in SWM systems. Interestingly, 22 respondents (6.9%) "highly disagreed" and 25 respondents (7.9%) "disagreed" with the notion that lack of awareness was a major contributor to inefficiency. These individuals likely believed that factors like inadequate funding, poor governance, or weak policy enforcement played a more crucial role in determining SWM outcomes. Similar trends were observed by Hassan, Nawaz and Iqbal [38], who noted that in some regions, public dissatisfaction with SWM systems was directed more toward institutional failures than individual behaviors, particularly when residents perceived themselves as adequately informed but let down by inadequate municipal services. A small number of respondents, 9 individuals (2.8%), selected "I don't know," indicating uncertainty or unfamiliarity with the topic. This response points to a knowledge gap among some participants, suggesting that awareness about the role of public knowledge in SWM might be lacking in certain groups within the population. Similarly, Zhang and Li [39] highlighted that lack of engagement and communication from municipal authorities often perpetuates uncertainty about SWM challenges and the role of public awareness in addressing them.

Table -3: Problems related to lack of awareness contribute to inefficient SWM

Level of agreement	Frequency	Percentage
Highly disagree	22	6.9
Disagree	25	7.9
Moderate	30	9.4
Agree	101	31.8
Highly agree	131	41.2
I don't Know	9	2.8
Total	318	100

3.5.3 Improper Solid Waste (SW) disposal as contributing factor to inefficient SWM

The findings revealed that a significant proportion of respondents identified improper solid waste (SW) disposal as a major factor contributing to inefficient solid waste management (SWM). Of the participants, 124 respondents (39.0%) "highly agreed," and 90 respondents (28.3%) "agreed," together accounting for 67.3% of the total responses, as shown in Figure 7. These results emphasized the critical impact of disposal inefficiencies—such as unregulated landfills, poor waste segregation, and inadequate disposal infrastructure—on the overall effectiveness of SWM systems. Similar trends were reported by Ahmed and Ali [34], who emphasized that improper disposal practices, particularly in urban areas of developing countries, often lead to the accumulation of waste, environmental degradation, and public health issues. A smaller portion of respondents, 56 individuals (17.6%), expressed moderate agreement. This suggests that while they acknowledged improper disposal as a factor, they may have seen it as just one of several interconnected issues affecting SWM systems. This highlights the complexity of the problem, where disposal inefficiencies are often linked to broader systemic challenges like funding shortages, poor governance, and limited public awareness. Smith, Jones and Taylor [29] observed that respondents in similar studies frequently rated improper disposal as a moderate concern when other issues, such as transportation or financial constraints, were perceived to be equally significant. On the other hand, 21 respondents (6.6%) "highly disagreed," and 22

respondents (6.9%) "disagreed" with the idea that improper SW disposal was a major contributor to SWM inefficiency. These individuals may have attributed inefficiencies to other factors, such as inadequate transportation systems, weak enforcement of waste management regulations, or limited public involvement in waste reduction efforts. Kumar and Gupta [35] noted that in regions with mismanaged waste systems, public dissatisfaction often shifts toward systemic governance failures rather than specific issues like disposal.

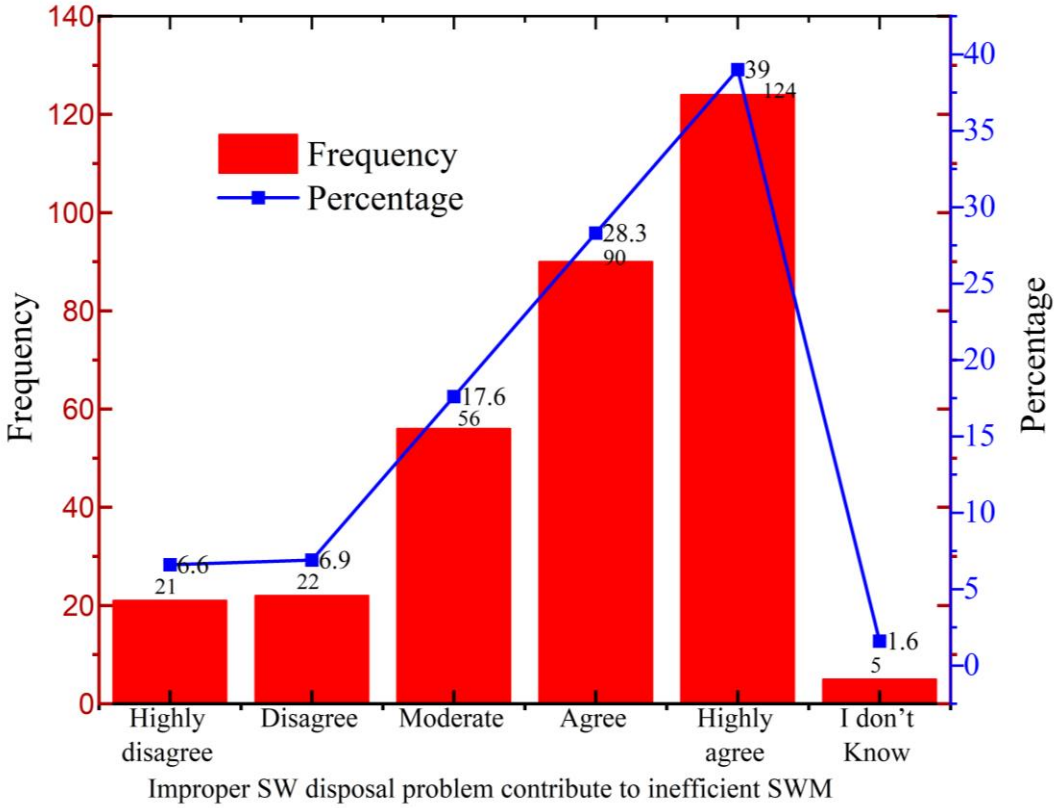

Fig -7: Improper SW disposal problem contribute to inefficient SWM

A small number of respondents, 5 individuals (1.6%), selected "I don't know," indicating uncertainty or lack of familiarity with the role of proper waste disposal in SWM inefficiencies. This response points to a potential gap in public understanding of the interconnected challenges within SWM, highlighting the need for better communication and educational efforts. Zhang and Li [39] emphasized that public awareness campaigns play a critical role in bridging knowledge gaps and fostering greater understanding of the importance of proper waste disposal. The high level of agreement (67.3%) highlighted the crucial role of proper waste disposal in ensuring efficient SWM. Disposal practices, such as landfilling, incineration, and composting, represent the final step in the waste management process and directly influence environmental and public health outcomes. Poor management of these practices can lead to environmental pollution, health hazards, and social disparities.

3.5.4 Poor community participation as contributing factor to inefficient SWM

The results showed that a substantial portion of respondents identified poor community participation as a key factor in the inefficiency of SWM. Of the participants, 113 (35.5%) "agreed" and 109 (34.3%) "highly agreed," combining for 69.8% of total responses as shown in Table 4. This high level of agreement highlighted the essential role of community involvement in the success of SWM systems. Inadequate participation in tasks such as waste segregation, recycling, and following disposal guidelines has been linked to exacerbating inefficiencies in SWM. Ahmed and Ali [34] similarly reported that inadequate community engagement was a major bottleneck in SWM systems, particularly in regions where public awareness campaigns and participatory initiatives were limited. A smaller group of respondents, 47 individuals (14.8%), rated their agreement as

"moderate," indicating that while they acknowledged poor community participation as a contributing factor, they may have also viewed other systemic issues, such as financial limitations or weak administrative structures, as equally important. Smith, Jones and Taylor [29] observed that community participation is often interlinked with other factors, such as governance and infrastructure, and that its impact on SWM efficiency is contingent on the broader socio-political context.

Interestingly, 27 respondents (8.5%) "disagreed," and 14 respondents (4.4%) "highly disagreed," combining for 12.9%. These respondents likely believed that other factors, such as inadequate infrastructure, insufficient funding, or administrative inefficiencies, were more significant contributors to SWM inefficiency than community participation. Brown and Taylor [30] noted that in regions with poorly managed SWM systems, public dissatisfaction often shifts toward institutional failures rather than individual or community-level shortcomings. A small percentage of respondents, 8 individuals (2.5%), selected "I don't know," indicating uncertainty or unfamiliarity with the role of community participation in SWM. This response suggests a possible gap in public understanding of how collective action and individual behavior can impact the effectiveness of SWM systems. Zhang, Chen, Zhang, Liu, Chen, Yang, Osman, Farghali, Liu, Hassan, Ihara, Lu, Rooney and Yap [36] emphasized that public education and engagement are critical for bridging knowledge gaps and fostering active participation in waste management processes. The high level of agreement (69.8%) underscores the importance of community participation in achieving efficient SWM. Active involvement from residents, businesses, and local organizations is essential for implementing critical waste management practices such as source segregation, recycling, and proper disposal. Ahmed and Ali [34] argued that community participation serves as the backbone of effective SWM systems, as it ensures that waste management policies and programs are supported and adhered to by the public. Community involvement also promotes accountability and transparency within SWM systems. When residents are actively engaged in waste management efforts, they are more inclined to oversee the performance of waste collection services and report any inefficiencies or irregularities.

Table -4: Poor community participation problem contributes to inefficient SWM

Level of agreement	Frequency	Percentage
Highly disagree	14	4.4
Disagree	27	8.5
Moderate	47	14.8
Agree	113	35.5
Highly agree	109	34.3
I don't Know	8	2.5
Total	318	100.0

3.5.5 Low technology as contributing factor to inefficient SWM

The results showed that a significant number of respondents identified low technology as a key factor contributing to inefficiencies in solid waste management (SWM). Among the participants, 126 respondents (39.6%) "highly agreed" and 98 respondents (30.8%) "agreed," making up a total of 70.4% of responses as shown in Figure 8. These findings emphasize the importance of technology in modernizing and enhancing SWM systems. The absence of advanced technologies, like automated waste segregation, GPS-enabled route optimization for waste collection, and waste-to-energy systems, likely impeded the efficiency and effectiveness of waste management operations. Similar trends were reported by Teshome [40], who highlighted that low technological adoption is a key limitation in waste management systems across developing countries, where reliance on manual and outdated processes continues to dominate. A smaller percentage of respondents, 44 individuals (13.8%), expressed "moderate" agreement, suggesting that while they acknowledged low technology as a contributing factor, they likely saw other systemic issues, such as weak administration, inadequate infrastructure, or financial constraints, as equally important. This finding aligned with observations made by Xiao, Dong, Geng, Francisco, Pan and Wu [41], who argued that technological limitations often operate in conjunction with broader governance and operational challenges, amplifying their impact on SWM systems. On the other hand, 28 respondents (8.8%) "disagreed" and 16 respondents (5.0%) "strongly disagreed" with the idea that low technology was a significant contributor to SWM inefficiency. These respondents may have

pointed to other factors, such as lack of public awareness, insufficient funding, or cultural resistance to waste management practices, as the main reasons for inefficiencies, rather than technological gaps. Zhang, Chen, Zhang, Liu, Chen, Yang, Osman, Farghali, Liu, Hassan, Ihara, Lu, Rooney and Yap [36] noted that in regions where waste management systems are underfunded or poorly governed, public perceptions often shift focus from technological deficiencies to more visible challenges, such as inconsistent waste collection or unregulated landfills.

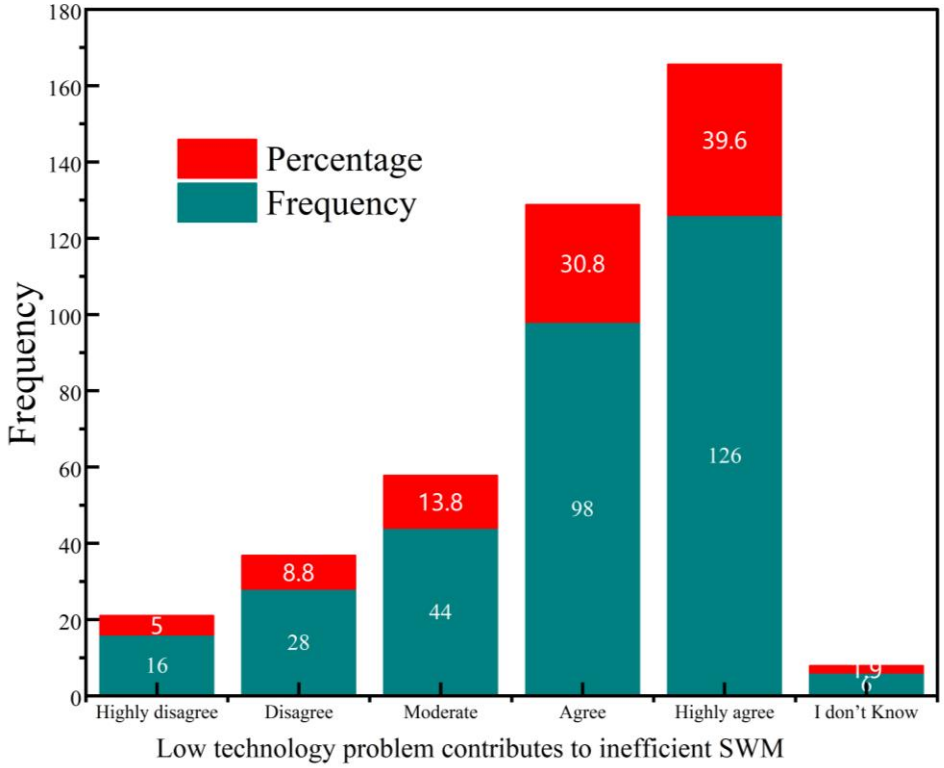

Fig -8: Low technology problem contributes to inefficient SWM

A small portion of respondents, 6 individuals (1.9%), selected "I don't know," indicating uncertainty or unfamiliarity with the role of technology in SWM. This response points to a potential knowledge gap, suggesting that some individuals may not fully grasp how technology can help resolve inefficiencies in waste management systems. Zhang and Li [39] emphasized that public awareness and education are critical for fostering understanding and acceptance of technology-driven innovations in SWM.

3.5.6 Rapid population growth as contributing factor to inefficient SWM

The results showed that a substantial majority of respondents recognized rapid population growth as a key factor contributing to inefficiencies in solid waste management (SWM). Of the participants, 132 respondents (41.5%) "strongly agreed," and 81 respondents (25.5%) "agreed," totaling 67.0% of all responses, as shown in Table 5. These findings highlighted the challenges caused by rising population densities in both urban and rural areas, which put pressure on the capacity of SWM systems. Similar conclusions were drawn by Bundhoo [42], who highlighted that population growth directly correlates with increased waste generation, creating additional pressure on already overburdened waste management systems in developing regions. A smaller group of respondents, 43 individuals (13.5%), showed "moderate" agreement, implying that while they acknowledged population growth as a contributing factor, they likely viewed other challenges, such as inadequate infrastructure, financial limitations, or poor administration, as equally important. Adewale and Ogunleye [43] highlighted that rapid population growth often interacts with systemic challenges, such as insufficient resources and governance failures, to exacerbate inefficiencies in SWM systems. Interestingly, 21 respondents (6.6%) 'strongly disagreed,' and 20 respondents (6.3%) 'disagreed' that population growth was a major factor in SWM inefficiency. These respondents

likely pointed to other challenges, such as a shortage of skilled labor, low technology adoption, or cultural factors, rather than population pressures, as the main causes of inefficiency. Getahun, Mengistie, Haddis, Wasie, Alemayehu, Dadi, Van Gerven and Van der Bruggen [44] observed that in regions with severe governance or operational challenges, public perceptions of waste management inefficiencies often shift away from population-related factors and focus on more visible issues, such as irregular waste collection or poor disposal practices. Another interesting finding was that 21 respondents (6.6%) selected 'I don't know,' indicating some uncertainty or unfamiliarity with the link between population growth and SWM inefficiencies, as shown in Table 6. This response points to a potential knowledge gap, highlighting the need for more public awareness about how demographic changes affect waste management systems. Guerrero, Maas and Hogland [45] argued that understanding the link between population dynamics and SWM performance is essential for designing effective policies and interventions. The strong agreement (67.0%) highlighted the significant impact that rapid population growth has on SWM systems. As populations grow, the amount of waste generated by households, businesses, and industries increases sharply, putting more pressure on waste collection, transportation, and disposal services.

Table - 5: Respondents agreement on RPG as contributing factor to inefficient SWM

Level of Agreement	Frequency	Percentage
Highly disagree	21	6.6
Disagree	20	6.3
Moderate	43	13.5
Agree	81	25.5
Highly agree	132	41.5
I don't Know	21	6.6
Total	318	100.0

4. Conclusion and recommendations

Municipal solid waste management is critical to the sustainable development of cities in developing countries because of limited municipal capacity, low bureaucratic efficiency, and lack of infrastructure. In this study, an assessment of municipal solid waste management (MSWM) practice was conducted in Menelik sub-city of Debrebrehan, Amhara region, Ethiopia. The study utilized a robust framework for data collection and analysis on municipal solid waste management (MSWM) in Menelik Sub-city. Primary data were gathered through field observations, interviews, focus group discussions, and questionnaires conducted in English and Amharic. A systematic sampling method ensured representation across three ecological zones. Data analysis combined quantitative techniques using SPSS and Origin Pro for statistical analysis and graphical representation, with qualitative approaches to identify patterns and causal relationships from open-ended responses and interviews. This mixed-method provided comprehensive insights into MSWM challenges. Analysis of waste generation rates reveals that individuals classified within low-income generated an average of 0.31 kg/cap/day whereas middle-income individuals produced an average of 0.49 kg/cap/day. High-income individuals produced an average of 0.67 kg/cap/day, which is more than twice the waste produced by those in the low-income category.

The study on municipal solid waste management (MSWM) in Menelik Sub-city provided a comprehensive analysis of the challenges, practices, and perceptions surrounding waste management systems. The findings revealed that the composition of municipal solid waste (MSW) in the sub-city was predominantly organic (60%), with recyclable materials accounting for 15% and other waste types comprising 25%. However, the collection and disposal processes were found to be suboptimal, with only 65% of waste being collected and disposed of properly, while 25% was dumped in uncontrolled areas, posing significant environmental and health risks. The study highlighted that the majority of households 84% utilized door-to-door waste collection services, demonstrating community adaptation to this method. However, variations in waste disposal frequency were observed, with only 38.7% of households disposing of waste daily, while a combined 61.3% disposed of waste less frequently (every 2-7 days or more). The majority of respondents perceived rapid population growth, low technology, poor community participation, improper SW disposal, lack of public awareness, economic constraints/financial issues as a

dominant drivers/contributing factor for inefficient SWM. The findings of the study highlighted that strengthening governance, increasing financial outlay, building the institutional capacity, stricter policy enforcement, fostering community participation, and implementing targeted public awareness campaigns are critical to ensuring sustainable and efficient waste management systems in the study area and beyond.

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Declarations

I confirm that the data included here is accurate and comprehensive. I hereby certify that this work has not been previously published and has not been submitted for publication to any journal

Conflict of interest: The authors don't have any competing interests

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