Municipal Solid Waste Management Practices in Urban Areas of Bhimdatta Municipality, Nepal

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Abstract

Effective municipal solid waste (MSW) management is essential for protecting public health, preserving environmental quality, and promoting sustainable urban development—particularly in rapidly urbanizing municipalities like Bhimdatta, Nepal. Despite national policies such as the Solid Waste Management Act (2011), many local governments continue to rely on unsustainable practices such as open dumping and unsegregated waste collection. This study aimed to assess the current status of MSW management in Bhimdatta Municipality by examining key aspects such as waste generation, composition, segregation practices, collection services, transportation methods, final disposal, and resource recovery. A mixed-methods approach was employed in Wards 4 and 18, which represent densely populated urban areas. Data were collected through structured questionnaires administered to 30 households, 63 commercial establishments, and 10 institutions, selected with a simple random sampling, key informant interviews with two municipal officials with purposively selected, and extensive field observations. Results revealed that 64.08% of respondents generated <0.5 kg of waste daily, dominated by organic waste (53%), followed by plastics/polythene (16%), and paper/cardboard (12%). Despite high satisfaction with door-to-door collection services, collection rates were high (86.40%), with 90.30% satisfaction, reasonable cost (81.55%), and convenient morning schedules (92.23%) significant gaps existed. 84.47% of respondents lacked waste segregation practices, and 95.14% of waste was transported manually via uncovered vehicles, causing spillage (9.71% occasional, 4.85% frequent). Final disposal relied on open dumping near a riverbank, 20 meters from settlements. Resource recovery efforts were minimal, with only 11.65% recycling plastics and 28.16% practicing composting. The study underscores an urgent need for targeted policies, strict enforcement of existing waste management regulations, and practical interventions—such as public awareness campaigns, infrastructure upgrades, and sustainable disposal technologies—to improve solid waste management practices.

Keywords: *Public awareness, resource recovery, urban solid waste, open dumping, waste segregation*

Introduction

The increasing volume of municipal solid waste (MSW) in urban areas globally poses a significant environmental and public health challenge. MSW encompasses a variety of discarded materials originating from households, institutions, and commercial establishments (Lema et al., 2019; Maharjan et al., 2019; Teshome et al., 2022). Implementing effective and sustainable MSW management is crucial for enhancing urban living conditions, protecting public health and environment, boosting economic productivity, creating safe and dignified employment, and fostering sustainable urban development (Ezeah & Roberts, 2012).

Globally, MSW is taken as a rising issue, especially in cities of low-income countries such as Nepal. In the context of Nepal, the urgency of addressing MSW is further underscored by the country's commitment to the United Nations Sustainable Development Goals (SDGs), particularly Goal 3 (Good Health and Well-being), Goal 11 (Sustainable Cities and Communities), and Goal 12 (Responsible Consumption and Production) (Aryal & Adhikary, 2024). The rising volume of MSW in urban areas is primarily driven by population growth, unplanned urbanization, changing consumption patterns, and improved lifestyles (Hoornweg & Bhada-Tata, 2012; Teshome et al., 2022). Globally, urban populations are projected to increase from 54% in 2015 to 66% by 2050, with annual MSW generation expected to increase from 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050, necessitating substantial financial investment and robust infrastructure (UNEP, 2024). This challenge is more pounced in lower-income countries, where the rate of increase is projected to surpass that of higher-income nations (Hoornweg & Bhada-Tata, 2012). Nepal's waste management systems face considerable pressure due to rapid and often unplanned urbanization, coupled with evolving consumption patterns, leading to increased waste generation and limited disposal options (Khanal, 2023). Nationally, the rate and composition of MSW are further influenced by variations in physical factors (e.g., altitude, temperature, rainfall, and humidity) and socioeconomic factors (e.g., population growth, urbanization, economic status, living standards, and consumption patterns). Across Nepal's 58 municipalities, about 1,435 tons of solid waste are generated daily, with urban areas contributing the majority at an average of 0.317 kg per capita per day (ADB, 2013).

Bhimdatta Municipality, situated approximately five kilometers east of the Indian border, exemplifies the challenges of rapidly urbanizing municipalities in Nepal. As a growing commercial hub, Bhimdatta experienced an average annual population growth rate of 2.28% between 1991 and 2021, driven largely by internal migration from surrounding hill and mountain districts (NSO, 2021). This demographic shift has intensified pressure on existing municipality's waste management systems. Field observations in the municipality reveal ineffective waste management practices, including scattered piles of plastic and paper waste, open burning, waste-clogged drains, and foul-smelling gutters.

Despite the enactment of the Solid Waste Management Act (2011) and Solid Waste Management Rules (2013), which promotes decentralized, integrated, and community-based waste management system (CBS, 2021), urging local authorities to adopt more effective strategies (Khanal, 2023). However, its implementation remains inconsistent. Waste segregation at the source is limited, and waste collection efficiency varies—ranging from 70–90% in major cities to below 50% in smaller municipalities (ADB, 2013). Alarmingly, many municipalities still rely on environmentally harmful disposal methods such as open dumping (21%), open burning (32%), and waste piling along riverbanks (27%) (CBS, 2021). These unsustainable practices pose severe environmental and public health risks, including soil and groundwater pollution, disease transmission, and degraded air quality (Ferronato & Torretta, 2019). Open burning of waste emits hazardous pollutants like carbon monoxide (CO), carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), and particulate matter (PM_{10}), contributing to air pollution and climate change (Wiedinmyer et al., 2014). Additionally, unmanaged waste sites emit harmful landfill gases such as CO_2, CO, nitrogen, hydrogen sulfide, and ammonia, exacerbating environmental risks (Pokhrel & Viraraghavan, 2005). Moreover, uncontrolled disposal contributes to heavy metal pollution in water, soil, and plants (Vongdala et al., 2019) and increases greenhouse gas emissions, particularly methane, a potent driver of climate change (Çetinkaya et al., 2018).

While efforts such as community composting and awareness campaigns have been initiated, Nepal's recycling rate remains low. The effectiveness of proper waste disposal and segregation practices varies across regions due to inadequate infrastructure and limited public engagement (ADB, 2013; Khanal et al., 2023). As a result, MSW remains a persistent challenge in urban Nepal (Maharjan et al., 2019), reflecting trends observed in other developing countries facing the compounded pressures of population growth and poorly planned urbanization (Ferronato & Torretta, 2019). These issues highlight the gaps in **localized waste management strategies,** as noted in studies of similar municipalities in Nepal (Aryal & Adhikary, 2024; Rai et al., 2019).

Although several studies have evaluated MSW management in major urban areas and larger municipalities in Nepal (Rai et al., 2019; Pandey et al., 2023; Awasthi et al., 2023), there is a notable lack of research on smaller yet rapidly urbanizing municipalities such as Bhimdatta. Addressing this research gap is critical, as sustainable waste management requires an integrated approach encompassing waste segregation, collection, transportation, resource recovery, and environmentally sound disposal, supported by community participation and awareness (ADB, 2013; Douti et al., 2017; Lema et al., 2019; Khanal et al., 2023). Accordingly, this study aims to conduct a comprehensive assessment of existing MSW management practices in Bhimdatta Municipality. The focus will be waste generation, composition, segregation, collection, transportation, disposal, and resource recovery processes. The findings will provide evidence-based insights for municipal authorities, policymakers, and relevant stakeholders to

formulate and implement effective, context-specific, and sustainable waste management strategies tailored to the challenges of Bhimdatta and similar municipalities in Nepal.

Materials and Methods

Ethics Statement

Research ethics is paramount in any scientific investigation, safeguarding the interests of the public, research participants, and researchers (Creswell, 2014). This study obtained formal ethical approval from Bhimdatta Municipality through a written consent letter. Prior to data collection, all respondents were thoroughly informed about the study's objectives, their voluntary participation rights, and their absolute freedom to withdraw at any time without any consequences. Consent was secured either verbally or by presenting the municipality-approved ethical approval letter. To guarantee the confidentiality and anonymity of participants, no identifying information was recorded during the data collection process.

Description of Study Area

Bhimdatta Municipality is located in the Kanchanpur District of Sudurpashchim Province, Nepal. Geographically, it lies between 28°52' to 29°08' North latitude and 80°06' to 80°15.5' East longitude (Fig. 1). The municipality covers an area of 171.24 square kilometers and exhibits predominantly flat terrain. However, its northern boundary reaches an elevation of approximately 1,192 meters above sea level, gradually sloping towards the south, where the lowest elevation is recorded at 222.5 meters (Bhimdatta Municipality, 2025). Administratively, Bhimdatta is divided into 19 wards. According to the 2021 national census, the total population stands at 122,320, with 27,570 households (NSO, 2021).

Climatically, Bhimdatta Municipality lies in Nepal's Terai region and experiences a tropical to subtropical climate with an average annual temperature that ranges from a summer maximum of 43°C to a winter minimum of 6.96°C. The municipality receives an average annual rainfall of approximately 1,575 millimeters, most of which falls during the monsoon season (Bhimdatta Municipality, 2025).

Economically, the municipality hosts a diverse and dynamic economy with major activities including agriculture, construction, wholesale and retail trade, vehicle and motorcycle repair services, financial and insurance services, hospitality, transportation and storage, government employment, and labor migration abroad (NSO, 2021). Formerly known as Mahendranagar, Bhimdatta is the oldest urban center in the region and was recently renamed through administrative decision. The municipality’s urban fabric consists of residential areas, governmental and non-governmental offices, educational and healthcare institutions, and commercial businesses. This diverse land use contributes significantly to the generation of municipal solid waste.

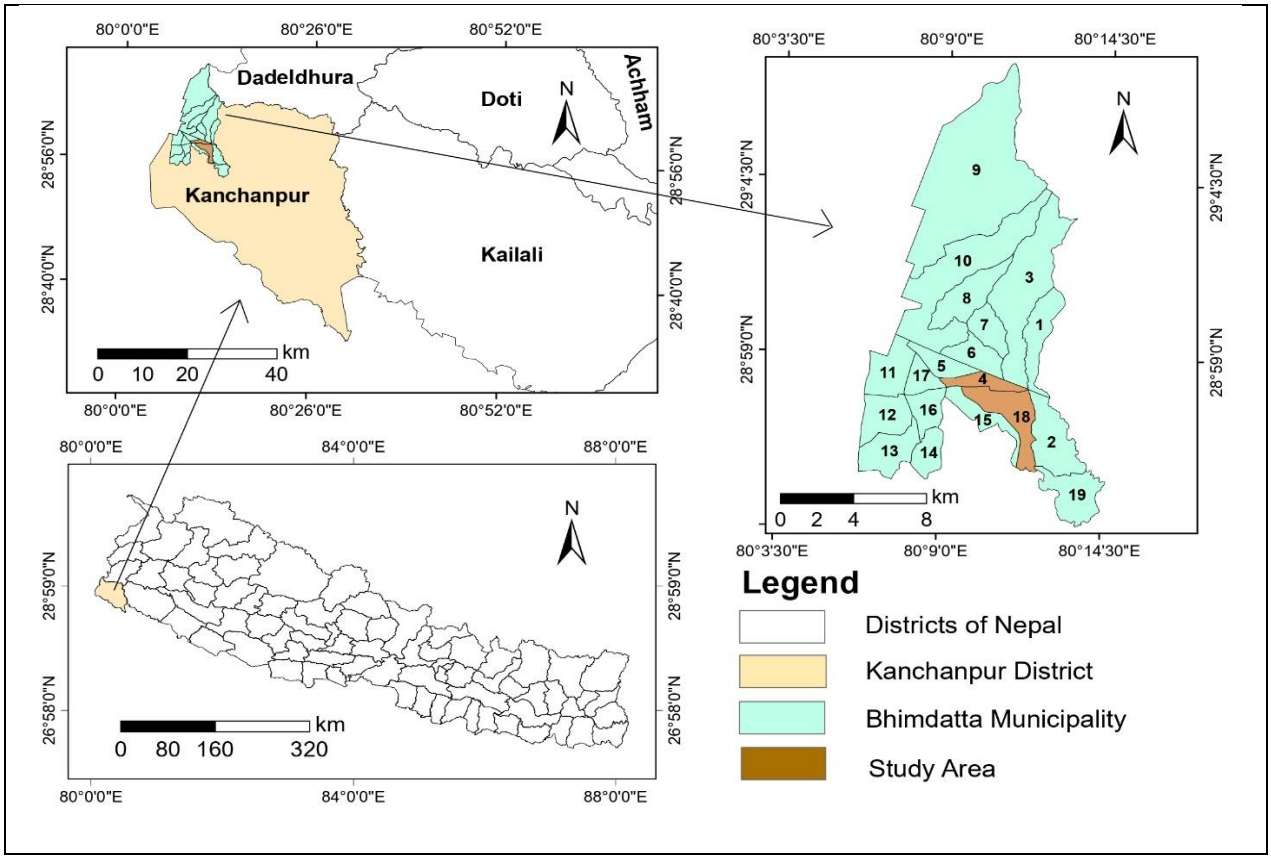

Fig. 1: Map of (a) Nepal, (b) Kanchanpur district, and (c) Bhimdatta Municipality showing study area

Research Design

The selection of an appropriate research design is fundamental for systematically collecting, analyzing, and interpreting data to address the research objectives effectively (Creswell & Creswell, 2017). This study, conducted from June 15 to June 30, 2024, employed a mixed-methods approach to integrate quantitative and qualitative data, thereby providing comprehensive and contextually rich insights into MSW management practices.

Due to logistical constraints—particularly limited resources and time—it was not feasible to directly quantify solid waste generation and composition using standardized field-based techniques such as the quartering method (Awasthi et al., 2023; Lohani et al., 2025) or commingled waste sampling at disposal sites (Pandey et al., 2023). Additionally, the absence of updated and reliable municipal records hindered the use of documentary analysis, despite its recognized methodological rigor (Mir et al., 2021). In response to these limitations, a structured, closed-ended questionnaire was employed to estimate daily waste generation and composition at the household, institute and commercial levels. Respondents were asked to select a predefined weight range that best represented their daily waste generation: <0.50 kg/day, 0.5–1.0 kg/day, 1.0–1.5 kg/day, 1.5–2.0 kg/day, 2.0–2.5 kg/day, 2.5–3.0 kg/day, and >3.0 kg/day. They were also asked to indicate the percentage composition of various waste categories (organic waste, plastic/polythene, paper/cardboard, glass, metal, dust, and others). The mean percentage values for each waste type were then calculated across all responses to determine the overall waste composition. These

results were visualized (Fig. 2 and Fig. 3) and analysed accordingly. Behavioral research supports the use of bounded estimation (using ranges) in enhancing the accuracy of self-reported data, as it minimizes over- or underestimation biases compared to open-ended questions (Tourangeau et al., 2000). Similarly, structured categorization has been shown to improve recall accuracy (Sudman & Bradburn, 1982). In many developing contexts, self-reported data on waste generation is often used due to similar practical constraints (Guerrero et al., 2013).

To complement the quantitative data, qualitative insights were gathered through structured questionnaires, key informant interviews (KIIs), and direct field observations. Moreover, triangulation of data from these multiple sources—specifically the cross-verification of questionnaire responses with KIIs and field observations—greatly enhanced the validity and credibility of the study's findings (Creswell, 2014).

Sampling Strategies

The study was conducted in Ward 4 and Ward 18 of Bedkot Municipality, Nepal. These wards were purposely selected due to their high population density and rapid urbanization, collectively accounting for 20.80% of the municipality's total population, with the majority residing in these areas (NSO, 2021). Previous studies, ADB (2013) and Lohani et al. (2025), have identified households, commercial establishments, and institutions as primary waste sources. These categories were retained in this study, as they remain representative of urban waste generation patterns (**Aryal & Adhikary, 2024; Awasthi et al., 2023).**

Respondents for the questionnaire survey were selected through simple random sampling, with one respondent per waste source category to ensure diverse representation. A total of 103 respondents participated: 63 from commercial establishments, 30 from households, and 10 from institutions. Additionally, two municipal officials—the Environmental Officer and the Head of Administration—were purposively selected due to their direct oversight of MSW management of the municipality.

Data Sources and Collection Procedures

Primary Data Collection

The following research instruments were employed for the collection of primary data.

Key Informant Interviews (KIIs)

KIIs were conducted with two municipal officials using a predefined questionnaire to gather detailed insights into the practice of MSW management, covering all stages from waste segregation to final disposal.

Structured Questionnaires

Data was collected using a pretested and updated structured questionnaire. It included closed-ended questions to assess waste generation rate, composition, segregation, collection, resource recovery, and final disposal, including public awareness and participation in MSW management activities. Questionnaires were administered in person to a representative from each household, commercial establishment, and institutional facility. The questionnaire was adopted from different previous studies and customized according to the study area setup. It was initially prepared in English and translated into the local language, Nepali.

Field Observations

Systematic field visits were conducted to validate data and capture real-time MSW practices. Observations included documenting overall MSW management practice. Photographic evidence was collected to support findings and enhance data triangulation.

Secondary Data Collection

Secondary data sources were collected from various relevant sources, including previous research studies, government/non-government reports, and news articles, to provide supporting information on MSW to analyses and interpret the study's findings.

Reliability and Validity

Prior to implementation, all research instruments were pilot tested on 10 households including commercials and institutions with similar attributes to the target population and then edited the questions to enhance clarity. To ensure data accuracy and reliability, a comprehensive two-day training session was provided to surveyors before field deployment, and throughout the fieldwork, the team leader closely supervised surveyors, providing ongoing guidance and necessary inputs to maintain high data collection standards.

Mapping and Data Analysis

ArcGIS 10.8 software was employed to delineate the study area, as shown in Fig. 1. The quantitative data collected through the closed-ended structured questionnaires were analyzed using descriptive statistics, such as frequencies and percentages. The results were presented through pie charts and graphs wherever necessary to enhance clarity and facilitate easy interpretation. MS Excel 2013 was used for this analysis. For the qualitative data obtained from interviews and observations, the responses were transcribed, coded, and categorized. The findings were then presented using direct and indirect quotations, employing expressive and persuasive language to effectively convey insights.

Results and Discussion

Waste Generation and Composition

A municipal official stated, "Although we expect solid waste generation to rise, the municipality has not yet collected any data on its generation or composition". This is despite Bhatta (2021) reporting in a news article that approximately 11 to 14 tons of waste were generated daily in the municipality.

The study revealed that most respondents (64.08%) generated less than 0.5 kg of waste per day, while 12.62% produced between 0.5–1.0 kg/day, and 8.74% generated 1.0–1.5 kg/day. Higher waste generation levels were less common, with only 14.56% of respondents reporting more than 1.5 kg/day, and a small fraction (5.83%) generating over 3.0 kg/day. Very high waste generation levels (2.0–2.5 kg/day and 2.5–3.0 kg/day) were rare, with only 1.94% of respondents in each category (Fig. 2). These findings align with trends in other developing countries, where per capita waste generation is typically lower than in developed nations. For instance, in developed countries, MSW generation ranges from 0.8 to 1.4 kg/capita/day (Bundhoo, 2018), whereas in developing countries, it ranges from 0.3 to 0.5 kg/person/day (Mir et al., 2021). In Nepal, waste generation rates vary, with studies reporting 0.317 kg/capita/day across 58 municipalities (ADB, 2013), 0.078 kg/person/day (Pandey et al., 2023), and 0.0347 kg/person/day (Awasthi et al., 2023).

The waste composition in the municipality was dominated by organic materials, averaging 53% (range: 48%–61%), followed by plastic/polythene (16%; range: 6%–18%), paper/cardboard (12%; range: 9%–22%), glass (4%; range: 2%–7%), and metals (3%; range: 0%–11%). Dust accounted for 9% (range: 7%–11%), likely due to sweeping practices, while other waste types made up 3% (range: 3%–6%) (Fig. 3). This composition suggests significant potential for composting and recycling, as highlighted by ADB (2013). These findings are consistent with previous studies in Nepal, where organic waste typically constitutes the largest portion of MSW (44%–65%), followed by plastics (14%–16%), paper (5%–11%), glass, and metals (ADB, 2013; Pandey et al., 2023; Awasthi et al., 2023). However, comparisons with other developing countries reveal variations. For example, in India, Mir et al. (2021) found that nearly 90% of respondents generated organic waste, while in Ethiopia, Teshome et al. (2022) reported that plastics/bags/bottles were the most common waste type (45%), followed by food waste (18.8%) and paper/cardboard (16.9%). Such regional variability underscores the influence of local consumption patterns, waste management practices, public awareness, and socio-economic factors (ADB, 2013; Douti et al., 2017; Mir et al., 2021).

Field observations indicated a complete absence of waste segregation at the source across households, commercial establishments, and institutions. Residential areas primarily generated small quantities of organic waste, such as food scraps and vegetable peels, alongside mixed waste. In contrast, commercial

establishments, including restaurants and shops, produced larger volumes of waste, with significant amounts of organic waste, plastics, and cardboard. Glass and metal waste were less common but more prevalent near beverage shops and restaurants, likely due to the disposal of bottles and cans. Dust, originating from sweeping activities, was a notable component of the waste stream in all zones. The overall waste composition included food waste, plastics, paper, textiles, rubber, metals, glass, dust, and hazardous materials, consistent with findings from previous studies in Nepal (ADB, 2013; Aryal & Adhikary, 2024).

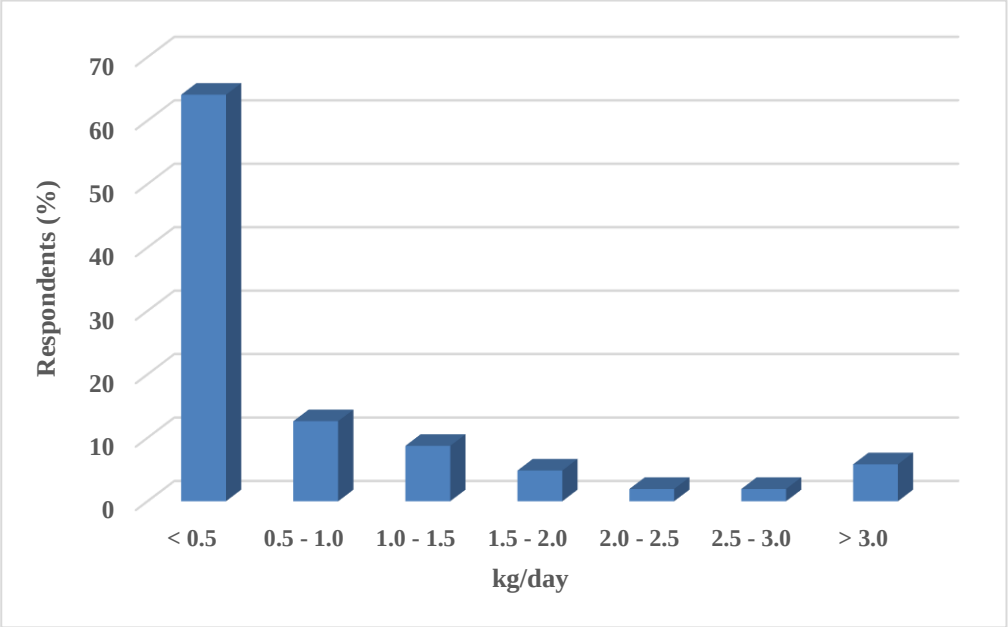

Fig. 2: Solid waste generated (in kg/day) on average by respondents

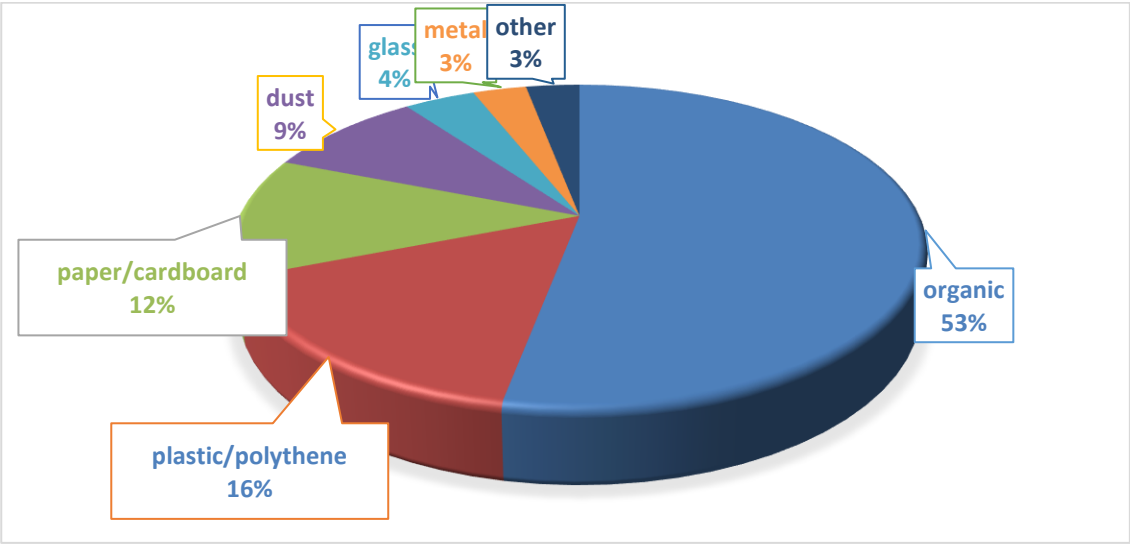

Fig 3: Average solid waste composition (in %) generated by respondents

Waste Segregation at the Source

The study revealed significant gaps in waste segregation practices, with 84.47% of respondents not segregating waste at the source. Only 15.53% practiced segregation, with 11 respondents using a two-category system (organic and inorganic) and 5 adopting a three-category system (organic, recyclable, and non-recyclable). The lack of segregation poses serious public health and environmental risks, as it allows hazardous materials, including healthcare waste, to mix with general waste, increasing the spread of infectious diseases like Hepatitis B and HIV (WHO, 2014) and complicating recycling processes (Maharjan et al., 2019). A key infrastructural barrier was the absence of separate waste bins, reported by 15.53% of respondents, underscoring the need for municipalities to invest in appropriate infrastructure to support segregation (Sen, 2022). The primary reasons for non-segregation included lack of enforcement (65.05%) and lack of awareness (18.45%), while only 0.97% cited inconvenience, indicating systemic issues rather than personal choice. These findings align with Aryal and Adhikary (2024), who emphasized the need for public awareness campaigns, stricter enforcement, and investment in segregation facilities to improve waste management in Nepal. This trend reflects broader national challenges, where ineffective enforcement, limited resources, and insufficient public engagement hinder waste management efforts (Maharjan et al., 2019). In terms of waste storage, 48.54% of respondents used open bins, 42.72% used bins with lids, 6.79% stored waste in plastic bags (posing hygiene and pollution risks), and 1.95% used other methods.

Observations confirmed that most households and institutional workers did not practice waste segregation. However, commercial units, such as restaurants, often implemented two- or three-category segregation systems (Fig. 4 b). Organic waste was typically sold to pig farmers, while other segregated waste was sold to informal waste pickers. Waste storage methods varied, with commercial units consistently using lidded bins. Although infrastructure for waste segregation was completed, no equipment, machinery, or processing plants have been installed.

Interviews revealed that colored bins were distributed to urban households and public spaces three years ago, alongside orientation sessions to promote segregation. However, financial constraints halted the initiative, leading to a decline in segregation practices, with some residents repurposing bins for non-waste uses. The lack of enforcement of segregation regulations further reduced compliance. Additionally, the waste segregation center, completed nearly four years ago, remains non-operational due to missing machinery and equipment (Fig. 4c).

Collection and Transportation

Interviews revealed that “door-to-door waste collection services were available in only 8 out of 20 wards, specifically Wards 4, 5, 6, 9, 10, 11, 18, and parts of Ward 3, in collaboration with a private partner. Waste collection occurred between 7:00 am and 1:30 am, with varying frequencies across wards. Wards

4 and 18 received daily collection services, while Wards 5, 6, 9, 10, 11, and parts of Ward 3 had collection on alternate days. In Ward 6, a private partner collected waste from a limited number of houses near the main highway. Public areas were managed by the municipality, though a limited workforce posed challenges in maintaining cleanliness and timely waste removal. The municipality owned six vehicles for waste collection: two tippers, three tractors, one backhoe, and a three-wheeler cycle operated by a private partner. However, this fleet was insufficient for daily demands, requiring multiple trips to the disposal site. Tippers and tractors, primarily used for door-to-door collection, were operated by a team of five staff members: one driver, two collectors, and two workers managing waste inside the vehicle*".*

The findings indicated that 86.40% of respondents received daily waste collection services, while 7.77% received service twice a week, and smaller proportions reported random, weekly, or once-a-week collection. High collection frequency is crucial in reducing illegal dumping and associated public health risks (Maharjan et al., 2019). Despite inconsistencies, 90.30% of respondents expressed satisfaction with the service, though 4.85% were dissatisfied, and an equal proportion remained neutral, suggesting areas for improvement. Financial participation was high, with 94.17% contributing to waste collection costs, and 81.55% finding the fees reasonable. However, 8.74% raised concerns about pricing, indicating a need for potential adjustments to address affordability, particularly for low-income households (Teshome et al., 2022). Collection timing was another critical factor, with 49.51% reporting collection between 7 am and 9 am, and 44.66% between 9 am and 12 noon. This morning schedule aligns well with residents' routines, facilitating waste disposal before other activities, as noted by Sen (2022). However, 5.83% reported random collection times, indicating inconsistencies that may require attention to maintain public trust. While 56.31% found the timing convenient and 35.92% very convenient, 7.77% found it inconvenient, suggesting a need for more flexible scheduling. The door-to-door waste collection system was highly valued for its convenience and effectiveness, with all respondents (98.06%) reporting direct waste collection from their sources, with a rare reliance on roadside pickup or alternative methods (e.g., burning). This system is widely implemented in high-income countries (Bezama & Agamuthu (2019), which contrasts with other municipalities in Nepal, where only 42.14% of households had access to door-to-door collection (Aryal & Adhikary, 2024). In Ethiopia, 60.6% of households have access, but 72.5% express uncertainty about collection frequency, leading to dissatisfaction (Teshome et al., 2022). Similarly, in Ethiopia, only 26% of households receive monthly door-to-door collection, contributing to improper disposal practices (Lema et al., 2019). Regarding waste transportation, 95.14% of respondents stated that their waste was collected by large vehicles (trucks or tractors), while the remaining respondents reported collection by small vehicles (e.g., three-wheeler cycle. All respondents noted that the collection of vehicles was uncovered, with 9.71% observing occasional spillage and 4.85% reporting frequent leakage. This finding aligns with Douti et al. (2017) and highlights the need for improved containment systems to mitigate environmental pollution (Meza et al., 2020).

Observations confirmed that tippers and tractors were the main vehicles for manual waste collection and transportation to the open dumping site. However, these vehicles remained uncovered during collection and transport, and workers were observed mixing segregated waste in the vehicles. To increase capacity, vertical frames were welded onto the tippers and tractors. Waste collectors wore basic protective gear like masks and gloves but lacked boots (Fig. 4d).

In developed countries, advanced algorithms are used to optimize waste collection routes, reducing costs and improving efficiency with specialized vehicles like skip loader trucks and compactors (Tirkolaee et al., 2019). In contrast, waste transportation in developing countries such as in Ghana, waste collection relies on a mix of manual and mechanical means, such as tricycles and skip loader trucks, but suffers from insufficient vehicles, poor road conditions, and irregular schedules, leading to overflowing containers and indiscriminate dumping (Douti et al., 2017). Furthermore, many municipalities in Nepal lack proper transfer stations, and waste is often transported directly to disposal sites using rickshaws, tractors, and dump trucks (ADB, 2013). Establishing transfer stations for further segregation and processing, as suggested by Maharjan et al. (2019), could streamline waste management and improve recyclable material recovery. These challenges are exacerbated by financial constraints, limited resources, inadequate infrastructure, rapid urbanization, a lack of public awareness, and administrative constraints, all of which hinder the development of efficient waste transportation systems (Douti et al., 2017; Teshome et al., 2022; Tirkolaee et al., 2019).

Final Disposal

Interviews revealed that the “waste was openly dumped at a temporary site in the Barakunda area of Ward Number 1 within the municipality. The municipality actively sought alternative sanitary landfill sites by negotiating with residents near government or private land. However, the process of using private land is complex and conditional. Landowners must submit a formal written request detailing the intended use of the land and obtain written consent from nearby residents before their land can be designated as a sanitary landfill site. As the current site nears capacity, the search for new temporary dumping sites is expected to continue”. This bureaucratic and community-dependent process reflects the municipality's lack of a comprehensive, long-term waste management strategy.

The findings further indicated a heavy reliance on municipal waste collection services, with 96.12% of respondents depending on these services for final waste disposal, which ultimately leads to open dumping. There was limited engagement of respondents in composting or burning. Field observations corroborated that **open dumping** remains the predominant disposal method. The **Barakunda dumping site,** situated at 28°59'28.1"N 80°11'46.0" E (Fig. 4e) is situated on **lowland terrain** near a **riverbank** and approximately **20 meters from human settlements**. The site was characterized by uncovered waste and

the presence of scavenging **animals (**Fig. 4f**)**. These findings align with studies conducted in other developing countries. For instance, Lema et al. (2019) in Asella town, Ethiopia, found that half of the respondents disposed of waste by dumping it in yards, ditches, rivers, or burning, a common practice in developing countries. Similarly, studies by Aryal and Adhikary (2024) in Nepal, and Birhanu and Berisa (2015) in Ethiopia, supported these observations. However, Douti et al. (2017) highlighted deficiencies in landfill management in urban areas of Ghana, including the lack of cell planning, improper waste compaction, absence of regular waste cover, and inadequate leachate and gas collection systems. Such substandard conditions, as noted by Owusu-Sekyere et al. (2013), pose serious public health and environmental risks if landfill standards are not met.

The study underscores the urgent need for environmentally friendly disposal methods, as current practices do not align with sustainable waste management principles (Maharjan et al., 2019). Transitioning from open dumping to more sustainable methods, such as engineered landfills or waste-to-energy facilities, is essential for mitigating health and environmental risks and promoting long-term sustainability (Scarlat et al., 2018). The prevalence of improper waste management practices is attributed to a lack of public awareness and inadequate municipal services (Lema et al., 2019). Similar challenges have been documented in India by Mir et al. (2021) and in Nepal by Maharjan et al. (2019), highlighting issues such as insufficient resources, lack of public awareness, and poor enforcement of waste management regulations.

Resource Recovery

The study revealed a significant gap in resource recovery practices, with 83.50% of respondents not engaging in recycling and only 2.91% occasionally recycling at the source. Among those who recycled, plastic was the most recovered material (11.65%), followed by paper/cardboard (1.94%) and glass (0.97%). Composting, a crucial resource recovery method, was practiced by only 28.16% of respondents. These findings align with previous research, such as Douti et al. (2017), and Teshome et al. (2022), which also identified low recycling and composting rates in urban areas of developing countries. In developing countries, over 50% of MSW is compostable, yet composting practices remain limited. Composting is a simple, sustainable waste management method that supports recycling and offers benefits such as bio-fertilizer production, pollution reduction, income generation, and low operational costs. Therefore, it is recommended that all developing countries adopt composting practices (Adhikari, 2022). The low rates of recycling and composting observed in the current study and previous research underscore the critical role of policy frameworks and community education in driving behavioral change. For instance, Krishna and Chaurasia (2017) demonstrated that effective recycling programs require not only infrastructure but also strong community participation and awareness. Effective resource recovery is essential for reducing landfill waste, conserving resources, and advancing the principles of a circular economy (Stępień et al.,

2019). By fostering a culture of recycling and composting, municipalities can significantly reduce their environmental footprint and promote long-term sustainability (Khanal et al., 2023; Krishna & Chaurasia, 2017).

Interviewees revealed that "*the municipality itself did not actively engage in resource recovery initiatives*. Although a biogas plant was previously installed and functioning to convert organic waste into biogas. It was mainly used for cooking in the municipality staff's quarter and had been non-operational for over a decade due to damaged components and the lack of repairs**" (Fig. 4g). Field observations confirm these findings, showing that the municipality still lacks resource recovery practices.** Instead, a small portion of residents engaged in limited resource recovery efforts, which were insufficient compared to the total waste generated (Fig. 4h). This underscores the urgent need for **institutional involvement, investment in recovery infrastructure,** and community engagement to enhance **sustainable waste management.**

Public Awareness and Participation

The study revealed varying levels of public awareness regarding solid waste management, with 18.45% of respondents reporting a high level of awareness, while the majority (58.25%) rated their awareness as moderate. Additionally, 9.71% reported low awareness, and 8.74% were uncertain about their level of awareness. Despite these differences, a significant majority (87.38%) expressed a willingness to volunteer community clean-up drives, indicating a strong public interest in improving waste management practices. This enthusiasm presents a valuable opportunity for local authorities to engage the public more effectively through targeted educational interventions (Sapkota et al., 2015). For instance, the involvement of youths in at-source segregation has been a positive trend in some urban areas, demonstrating the potential for youth engagement to drive behavioral change (Khanal et al., 2023). In Bhimdatta Municipality, sanitation workers used whistles during clean-up drives to attract attention and encourage residents to participate. This initiative successfully engaged social organizations, community police, journalists, and political leaders, fostering a collective effort to maintain cleanliness, as reported by Bhatta (2016), in a news article. To capitalize on this enthusiasm, local authorities should prioritize interactive and modern approaches to awareness campaigns. The study found that 38.83% of respondents favored workshops and training programs, while 31.07% preferred social media outreach. Additionally, there was almost equal preference for school programs and the use of banners and posters. However, the study also uncovered a significant communication gap between local authorities and the community. While 87.38% of respondents reported receiving no information, only 1.94% occasionally received information from the municipality about waste management. This lack of communication highlights the need for improved information dissemination and transparency to foster better community engagement and participation (Khanal et al., 2023). Moreover, when respondents were asked about the best method of waste disposal,

composting emerged as the most favored option, with 72.82% of respondents supporting it. Additionally, 18.45% of respondents believed that a combination of composting and burning would be effective, while a smaller percentage (4.85%) favored burning alone. Notably, 3.88% of respondents considered dumping waste near riverbanks as a viable method, which highlights a concerning lack of awareness about the environmental hazards associated with such practices. This lack of awareness is particularly troubling, as improper disposal methods can lead to water contamination and other ecological issues (Lema et al., 2019). A significant 89.32% of respondents admitted they were unaware of the municipality's final waste disposal methods, while only 10.68% claimed to know about it. This indicates a major gap in public awareness regarding post-collection waste management, which could limit community participation in improving waste management practices. Lack of transparency about disposal methods may also reduce public trust and hinder efforts to promote waste reduction and proper segregation (Mir et al., 2021).

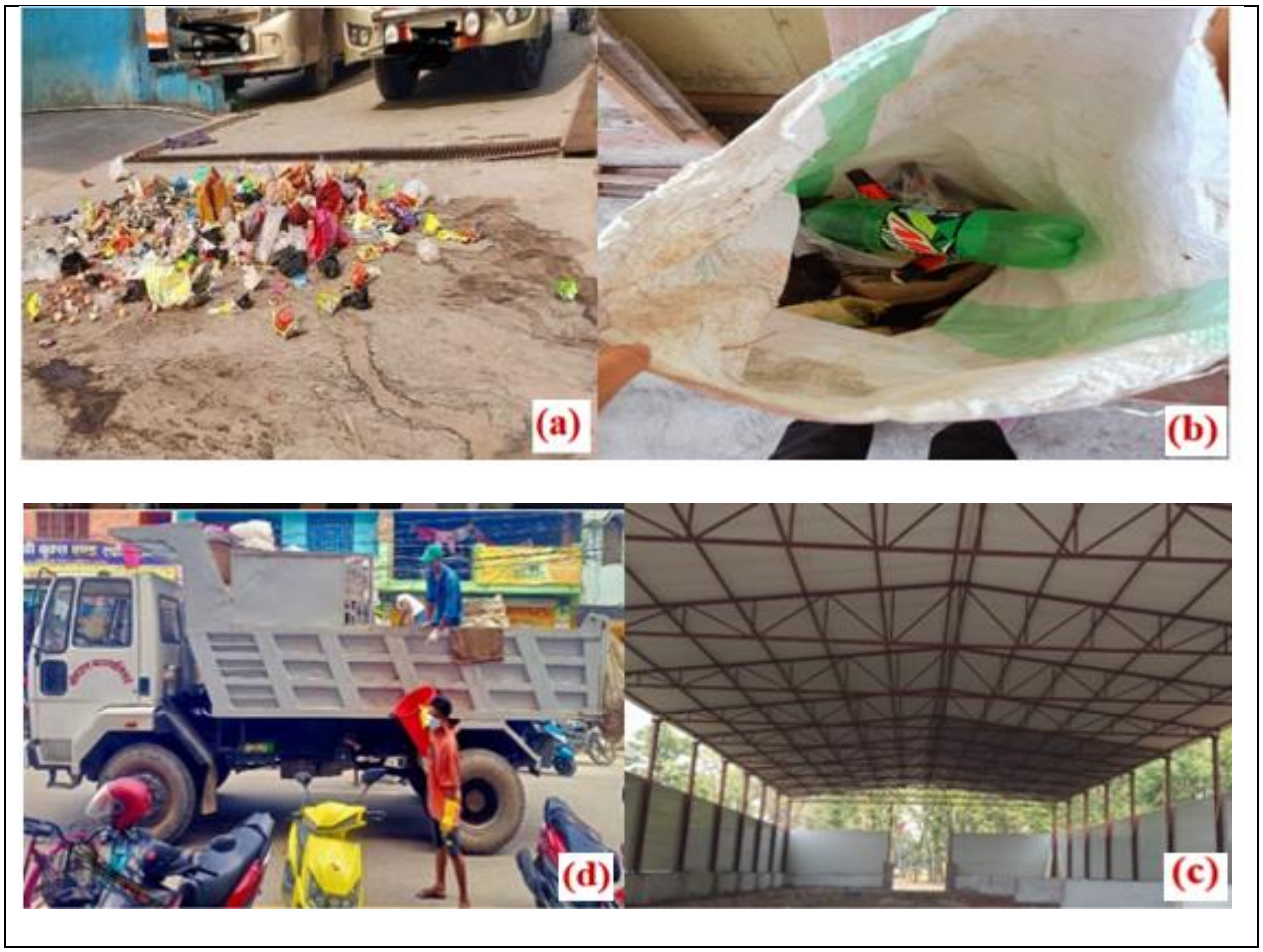

Fig. 4: (a) Scattered piles of waste, (b) Segregated waste at the restaurant, (c) Segregation center had not started yet, (d) Door-to-door collection and transportation by larger vehicle,(e) Google maps of dumping site at Ward Number 1, (f) Open dumping, (g) Waste-to-energy (Biogas) plant, (h) Reuse of non-biodegradable waste (rare), (i) Municipal official (in between) for an interview, and (j) Questionnaire survey with the respondents,

Conclusions

The study assessed existing municipal solid waste (MSW) management practices in Bhimdatta Municipality, a rapidly urbanizing area in Nepal. Key findings revealed that most respondents generated less than 0.5 kg of waste daily, with organic (53%) waste dominating the stream. Crucially, waste segregation at the source was largely absent, with only 15.53% of respondents practicing it. While waste collection services were generally reliable (86.40% of respondents) via door-to-door services using non-mechanized vehicles (tippers or tractor), and transportation was inefficient due to uncovered vehicles leading to spillage (9.71% occasional, 4.85% frequent). Final disposal relied heavily on open dumping. Resource recovery practices like recycling and composting were limited, with only 28.16% of respondents engaging in composting and plastic being the most recycled item (11.65%). Although public awareness towards waste management was moderate (58.25%), a strong willingness to participate in community clean-up drives (87.38%).

Implications

The findings highlight the pressing need for targeted policies and practical interventions to enhance solid waste management in Bhimdatta Municipality. Priority actions include stricter enforcement of the Solid Waste Management Act (2011) and Solid Waste Management Rules (2013), alongside public awareness initiatives aimed at promoting waste segregation and proper waste management practices. These efforts should be supported through educational workshops, training programs, and the use of social media. Additionally, infrastructure improvements—such as the provision of segregated waste bins and the deployment of covered waste-collection vehicles—are essential. The implementation of verified segregated collection systems, expansion of community-based composting and recycling initiatives, and the adoption of sustainable disposal technologies, including engineered landfills and waste-to-energy facilities.

Limitations of the Study

This study has several limitations. First, studies should employ direct quantification methods to obtain more accurate data. Second, the study was conducted in specific urban areas of the municipality with a relatively small sample size of 103 respondents, which may limit the generalizability of the findings to other regions or municipalities in Nepal. Finally, the study was conducted over a short period, which may not account for seasonal variations in waste generation and management practices.

Recommendations

To address the identified challenges, the following practical solutions are recommended:

- Strengthening enforcement of existing waste management regulations and investing in infrastructure to support segregation and recycling.
- Launching targeted educational programs, including workshops, social media outreach, and school initiatives, to raise awareness and encourage community participation.
- Implementing mandatory waste segregation at the source, supported by the distribution of at least three color-coded bins.
- Promoting recycling and composting through incentives, improved infrastructure, and community engagement programs.
- Developing engineered landfills (e.g., sanitary landfills) or waste-to-energy facilities to replace open dumping.

Future Research Directions

Future research should employ direct quantification methods, such as quartering waste sampling techniques, to obtain more accurate data on waste generation and composition. Longitudinal studies should be conducted to assess seasonal variations in waste generation and management practices.

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