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Solid Waste Characterization, Quantification and Management Practices in Southern City of Central Nepal: A Case Study of Jeetpursimara Submetropolitan City

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Abstract

The problem of waste is emerging in the growing cities of Nepal. Waste management has become a serious environmental and public health issue for most local governments of Nepal. This paper assesses the status of solid waste management in Jeetpursimara Sub Metropolitan City (JSSMC) in southern Nepal focusing on waste generation patterns, management practices, and institutional capacities. The major sources of waste in JSSMC were households, business, industries, and health and education institutions. The per capita household waste generation and the total municipal solid waste generation was found to be 125 g/day and 14.92 tons/day (5445.8 tons/year) respectively. The organic waste was found to be in majority (56%) and the rest to be inorganic in nature. JSSMC doesn't manage the municipal waste directly but has made a contract with the private company that provides municipal services such as sweeping and also a collection of wastes from households and commercial areas. The city lacks a transfer station, and the collected waste is transported directly to the dumping site. At the dumping site, recycling activities are carried out, but the amount of waste recycled is relatively low, representing only 15-20% of the total waste collected. The annual average expenditures of waste management were observed to be USD 67,800. The development of a well-managed waste treatment facility has been recommended for the proper management of the increasing problem of solid waste.

Keywords*:* waste management, composition, institutions, local government, Terai

1. Introduction

The unwanted substances which are often the leftover or the refuse are solid waste (Jatput et al., 2009). They are the useless and unwanted products resulting from human activities (Sharholy et al., 2008). It can be classified as materials reused or gathered, put away, or

treated some time recently, reusing or being utilized in a way constituting transfer, burned for vitality recuperation, recovered, and amassed, or a disposed of fabric that's reused, and intrinsically waste-like (Hoornweg and Bhata, 2012; Ramachandra, 2006). Waste is an unavoidable by-product of most human activity. Financial improvement and rising living standards have driven to increments within the amount and complexity of created solid waste, while mechanical enhancement and the arrangement of extended healthcare offices have included significant amounts of mechanical waste and biomedical waste into the waste stream with possibly extreme environmental and human wellbeing consequences (UNESCAP, 2007).

Generation of solid waste are related to resource consumption and land-use distribution. The sources can be classified as residential, commercial, institutional, development and pulverization, metropolitan administrations, treatment plant locales, industrial, and agricultural (Tchobanoglous & Kreith, 2002). Municipal solid waste is created from family units, workplaces, lodgings, businesses and other institutions. Wastes includes plastic, paper, glass, metals, as well as the construction debris and very small proportion of hazardous waste, and electric and electronic waste (Reddy, 2011; Tchobanoglous & Kreith, 2002).

In Nepal, along with other pollutants such as air (Gurung & Bell, 2013), water (Adhikari et al., 2021; Gurung et al., 2019; Pokhrel et al., 2009) and noise (Chauhan & Bhatta, 2019; Chauhan et al., 2021), solid waste is also emerging as a major environmental and public health concern (Dangi et al., 2011; Pathak et al., 2020). Solid waste collection, transportation and street-sweeping are usually done by the local governments for which the average municipal budget allocated is about 10% of the total budget (Maskey, 2018; Rai et al., 2019). Yet, there's no legitimate and compelling waste collection and management framework leading to an erratic disposal and burning heaps of waste along the streets and riversides (CBS, 2020a).

Urbanization has intensified the pressure on municipal waste management systems, with cities like Jeetpur Simara Sub-Metropolitan City (JSSMC) facing growing challenges in waste collection, segregation, and disposal (ADB, 2013). Recent studies highlight that inadequate infrastructure, limited financial resources, and weak institutional frameworks are major barriers to effective SWM in South Asia (Shrestha et al., 2021; Joshi & Ahmed, 2021). The composition of municipal solid waste (MSW) in Nepal is predominantly organic, reflecting the region's reliance on fresh produce and limited use of packaged goods (Adhikari & Dahal, 2018). However, the increasing presence of plastics and other non-biodegradable materials poses significant environmental and public health risks, particularly in the absence of proper recycling and disposal mechanisms (Sharma et al., 2020).

Furthermore, the COVID-19 pandemic has exacerbated these challenges, disrupting waste collection services and increasing the generation of medical and hazardous waste (UNDP, 2020; Shrestha et al., 2021).

There are several waste related legislations in Nepal. Solid Waste Management Act, 2011 is the dedicated act for managing solid waste. Local Government Operation Act 2017 makes local government responsible for waste management. The Environment Protection Act, 2019 focuses on hazardous waste management and import and export of waste. However, the enforcement of this legislation has not been effective (Pathak et al., 2020; Rai et al., 2019). Existing legal instruments are adequate in managing solid waste in Nepal. However, the management of resources, implementation of SWM policies, and commitment from all level of governments is required for the compelling waste management system (Dangi et al., 2017).

Several studies on solid waste have been carried out in Nepal. However, most of them are concentrated in Kathmandu Metropolitan City. Before choosing the most effective waste management option, the waste outputs and characteristics such as the volume and type of waste, management practice, resource allocations, the responsible actors should be understood. In this context, this paper examines the status of solid waste management in JSSMC, focusing on waste generation patterns, management practices, and institutional capacities.

2. Materials and Methods

2.1 Study area

This study was carried out in Jeetpursimara Sub Metropolitan city (JSSMC) of Madhesh Province, Central Nepal (Figure 1). This city lies (between 27°4'20" to 27°15'30" N and 84°56'55" to 85°7'15' E) in southern part of Nepal. It has 24 wards and an area of 312.6 Km^2. JSSMC is surrounded by Nijgadh, Kolvi, Kalaiya municipalities and Parsa and Makawanpur districts. According to 2021, census, the sub-metropolitan city has a population of 127,307 people with the population density of 409.2/km^2.

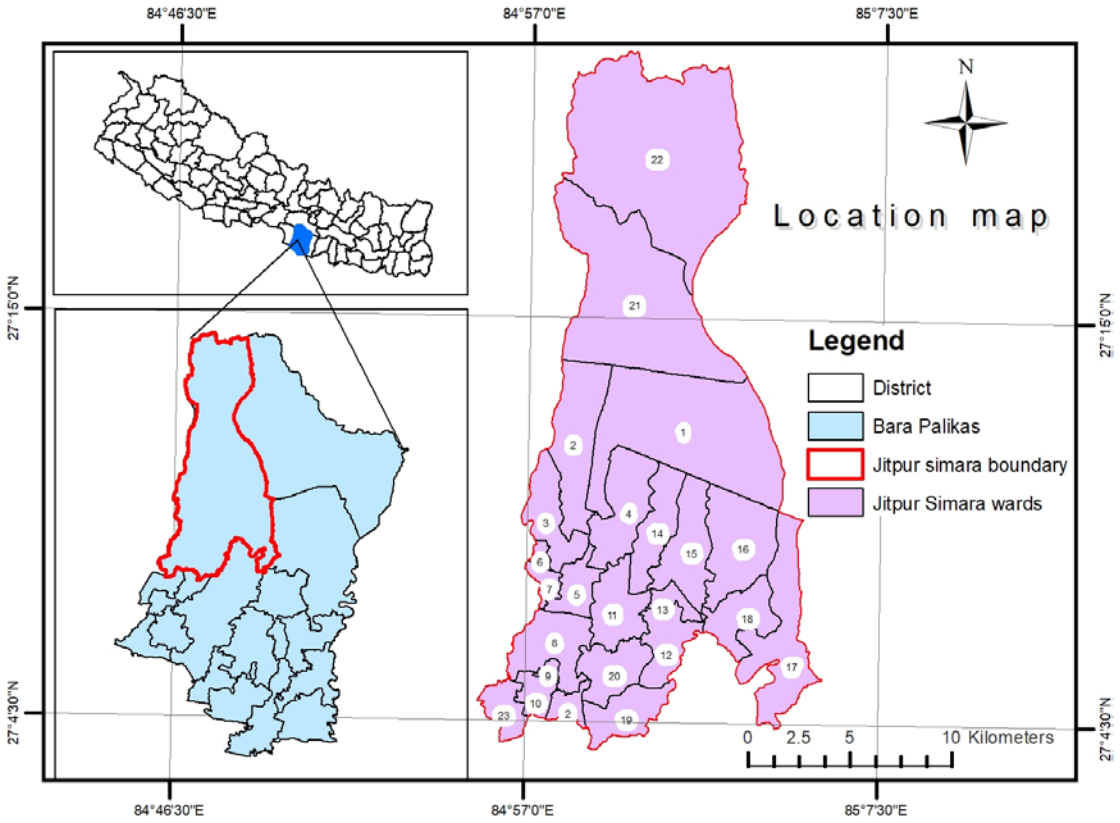

Figure-1: Location of the study area

JSSMC has an elevation of 91 masl to 801 masl. It has a tropical climate prevailing. It is warm every month in summer and cold in the usually dry winter season. The average annual temperature for JSSMC is 25°C and there is about 1909 mm of rain in a year. The highest temperature is observed in May (34.9 °C) and the lowest temperature is observed in January (7.7 °C) as shown in Figure 2. Most of the precipitation occurring in June, July, August and September with the highest rainfall of 581 mm in July. The lowest amount of rainfall is 5mm in November.

Lands within JSSMC can be categorized under seven types, viz. built up, agriculture, forest, water body, barren land, scrubs and grassland. The major part (18,892.46 ha) of the site is covered by forest are and agriculture (8223.6 ha), built-up (2391.66 ha), water bodies (243.98 ha) and barren land (767.64 ha), grassland (1.52 ha) and Scrubs (603.04 ha) (Karra et al., 2021). Ward numbers 1, 2, 3, 4, 14, 15, 17, 21, and 22 are mostly covered by forest. Similarly, most of the urban and suburbs with the greater built-up area are located inward numbers 2, 3, 4, 5, 6, 7, 8, 9, 10, 14, 15 and 23.

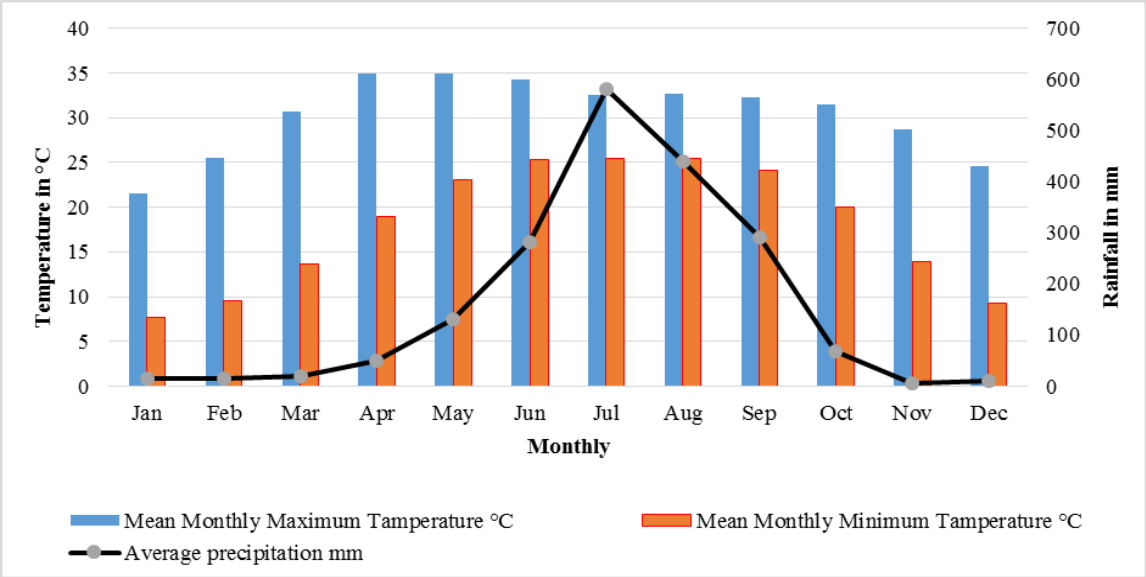

Figure-2: Climatic of JSSMC (Record from Simara Airport 1981-2010)

2.2 Data Collection

A rapid waste management survey was conducted in JSSMC. Two kinds of the survey were done. First, the survey was designed and deployed to a sample of 100 households using stratified random sampling, and second, the survey was also designed for the waste management actors. Consultations were done with a wide range of stakeholders including the heads and officials of Environment and Disaster Management of Division of JSSMC, waste managers and waste workers to understand existing waste management approaches and management capacity. The survey and consultations focused on gathering baseline information and data on SWM including the amount and composition of MSW, and other crucial data around the state of SWM in JSSMC. A literature survey was conducted and secondary data were collected from different published works. Adhikari & Dahal (2018) and Dahal & Adhikari (2018) have studied solid waste management in JSSMC in the past. Besides, the annual plan and budgets of JSSMC, Palika and ward profiles, news articles related to waste management in JSSMC were also reviewed as part of the data collection. The data collection was dome amid the second wave of CoVID-19. Therefore, several difficulties were faced in conducting the survey and collecting data.

2.3 Data Analysis

Data entry was done in MS excel and the descriptive statistics were computed at ward level. Charts and figures were also prepared using R-software, version 3.5.1 (Team, 2016).

3. Results and Discussion

3.1 Major sources of Solid Waste

Out of the studied wards, the municipal wastes observed were categorized into four different categories on the basis of the sources of waste (Table 1). These include household, commercial, industrial waste, and institutional wastes from educational and health sectors.

Table-1: ***Solid wastes categories in JSSMC***

Sources	**Waste generation, activities and units**	**Waste types**
Residential	Single-family and joint family	Paper, cardboard, food wastes, plastics materials, wood, glass, tin cans, aluminum, other metal, leather, shed wastes, cinders, road clears out, customer gadgets, oil cans, tires yard squanders, and batteries
Commercial	Workplace buildings, restaurants, hotels, stores, markets, impress shops, auto and metal workshops	Food wastes, vegetables waste, Paper, cardboard, plastics, wood, glass, metal wastes, automobile engine oil, textiles
Institutional	School, hospitals (excluding hazardous waste)	Paper, cardboard, plastics, glass, metal wastes, textiles
Industrial	Construction, manufacturing, chemical plants	Paper, plastics, metal wastes, chemicals

The categorization of solid waste into household, commercial, institutional, and industrial sources aligns with global waste management practices, as highlighted by Hoornweg and Bhada-Tata (2012). The dominance of organic waste in household waste is consistent with findings from developing countries, where food waste constitutes a significant portion of municipal solid waste (MSW) due to high consumption of fresh produce and limited packaging (Wilson et al., 2015). The presence of plastics and paper in commercial and institutional waste reflects the reliance on disposable materials in these sectors, a trend observed in urban centers globally (Kaza et al., 2018). The inclusion of industrial waste, particularly from construction and manufacturing, underscores the need for specialized waste management strategies, as these wastes often contain hazardous materials requiring careful handling (UNEP, 2015).

3.2 Waste Generation and Collection

In Jeetpursimara Sub-Metropolitan City, waste generation (household-person) is estimated to be 125 g/day. Based on the waste generation estimates and the projected population of 2021 which is 119,369, the total waste generation of JSSMC was estimated to be 14.92 tons/day (5445.8 tons/year) which incorporates 13 tons/day squanders from family, 1.5 tons/day from businesses and 0.42 tons/day from institutions. The ward wise distribution of waste generation is shown in Figure 3 which depicts that the highest waste generation was found in ward no. 16 and lowest waste generation in ward no.13 of JSSMC.

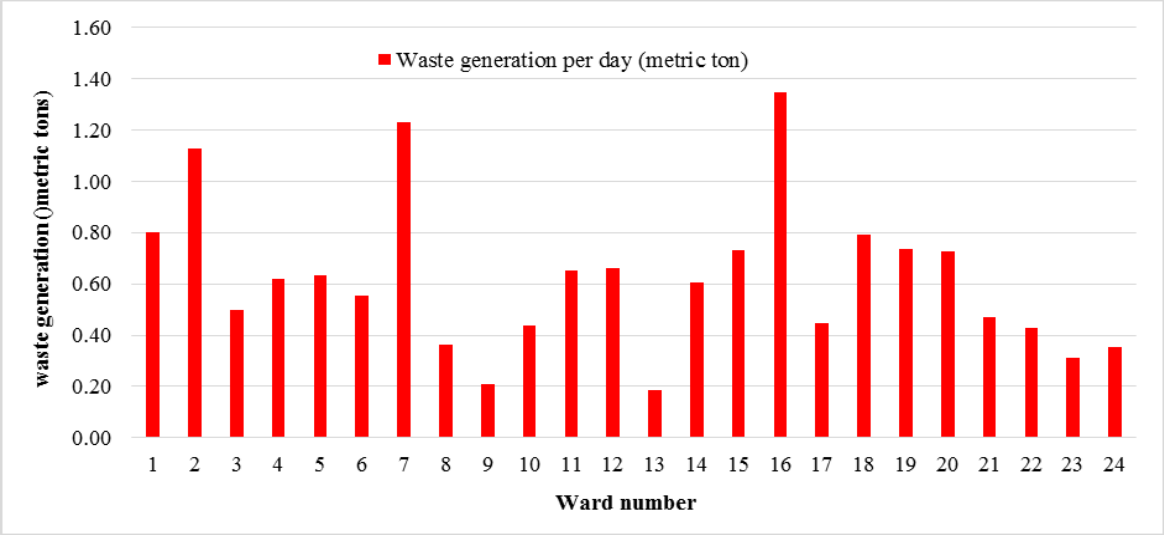

Figure-3: Ward wise waste generation in JSSMC

The waste generated in JSSMC was classified into three main types: organic, inorganic, and other waste. While solid waste could be divided into various categories, these three groups were selected for their distinct and easily identifiable components, aligning with classifications commonly referenced in research and practical applications (Tchobanoglous & Kreith, 2002). Figure 4 illustrates the general composition of municipal solid waste (MSW) and its distribution across household, commercial, and institutional sectors in JSSMC. The proportions of organic, plastic, and paper waste vary by sector. Household waste primarily comprises organic material (80%), whereas paper and paper-based products dominate in commercial and institutional waste, constituting 59% and 41%, respectively (Adhikari & Dahal, 2018).

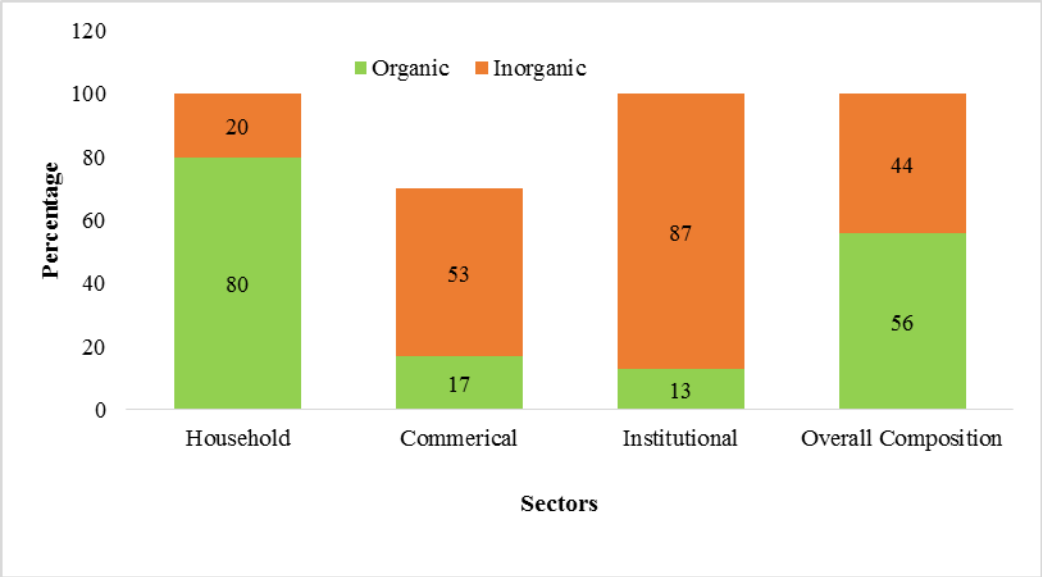

Figure-4: Composition of solid waste in the household, commercial, institutional waste and overall aggregate

The survey identified organic waste as a significant category of waste generated by municipalities, accounting for 56% of the total composition. This includes agricultural and garden waste, paper, textiles, leather, and other organic materials (Figure 5). Inorganic waste in JSSMC consists of materials such as plastic, glass, rubber, metals, minerals, and other non-organic items. Among these, plastic was a prominent component across all sources, comprising 17% of the total, with contributions of 10% from households, 33% from institutional sources, and 21% from commercial sources. Waste types such as hospital waste, electronic and electrical waste (e-waste), toxic waste, and other chemical waste, which do not fit into the organic or inorganic categories, were classified as "other waste." These waste types were observed in smaller quantities, as Nepal's waste management regulations require institutions and industries to manage their own waste.

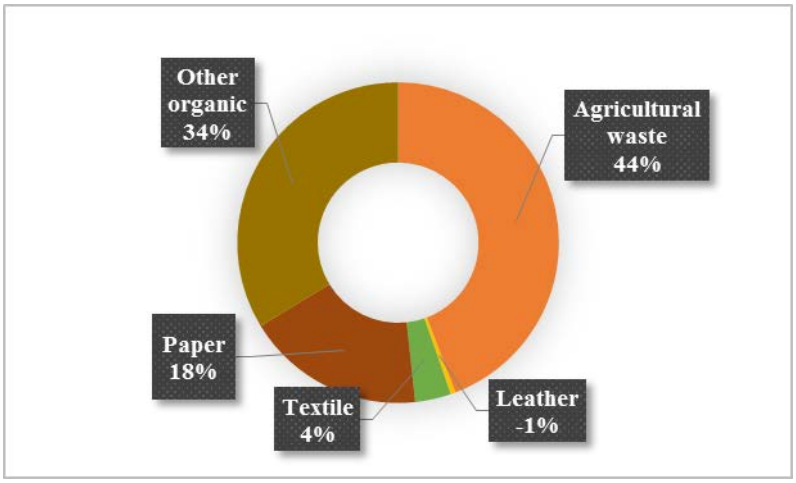

Figure-5: Composition of organic waste in JSSMC

Waste generation rates are influenced by various factors, including geographical location, seasons, kitchen waste utilization practices, collection frequency, regional service characteristics, on-site processing, dietary habits, economic conditions, recovery and reuse practices, waste management regulations, cultural beliefs, population growth, climate, and household size (Darban Astane & Hajilo, 2017). A survey conducted by ADB in 2013 highlighted that household waste generation rates vary based on financial status and climatic conditions. The study reported an average per capita household waste generation of 170 grams per day. Households with monthly expenditures of NRs 40,000 ($417) or more produced over twice the waste of those spending less than NRs 5,000 ($52) monthly (ADB, 2013).

The analysis of household waste composition showed that organic waste was the most significant category, making up 66%, followed by plastics at 12% and paper products at 9%. In institutional waste, paper products dominated at 45%, while organic waste and plastics accounted for 22% and 21%, respectively. Commercial waste consisted of 43% organic waste, 23% paper and paper products, and 22% plastics. Overall, municipal solid waste (MSW) was comprised of 56% organic waste, 16% plastics, and 16% paper (ADB, 2013).

The per capita waste generation rate of 125 g/day in JSSMC is lower than the global average of 250 g/day (World Bank, 2018), which may be attributed to lower consumption patterns and limited industrialization. However, the high proportion of organic waste (56%) is consistent with findings in other South Asian cities, such as Dhaka and Kathmandu, where organic waste constitutes 60-70% of MSW (Ahmed & Ali, 2004). The variation in waste composition across sectors highlights the need for tailored waste management strategies. For instance, the high paper content in institutional waste suggests opportunities for recycling,

while the prevalence of plastics in commercial waste calls for stricter regulations on single-use plastics (Kaza et al., 2018). The influence of socioeconomic factors on waste generation, as noted by ADB (2013), underscores the importance of integrating waste management with broader development goals, such as poverty alleviation and sustainable consumption.

3.3 The Approach of Waste Management

In JSSMC, municipal sweeping involves cleaning roads and public spaces, serving as a key indicator of the city's cleanliness practices. The municipal sweeping services is mainly done in the major urban areas of ward 1, 2 and 7. About 17 staff are involved in municipal sweeping. Several practices of waste management can be observed that have been adopted by the local governments of Nepal.

A survey conducted by the Central Bureau of Statistics highlighted various waste management practices adopted by municipalities. Most municipalities utilized one or more waste management methods. The three primary methods included: (i) disposal in landfill sites, practiced by 48.6% of municipalities, (ii) burning, adopted by 32.1%, and (iii) piling waste along riversides, practiced by 27.4%. Among different municipal categories, 60% of metropolitan and sub-metropolitan cities and 47.7% of municipalities used landfill sites for waste disposal (ADB, 2013; CBS, 2020b).

Three patterns of waste management can be observed in Nepal. First, waste management is solely done by local governments including the management of finance and human resources. Second, the involvement of private sectors and non-government organizations. The third practice involves the mixed type with the involvement of both the government and private sector. JSSMC doesn't manage municipal waste directly but has made a contract with a private company called Green and clean city Pvt. Ltd., JSSMC provides a contract number of NRs 72 lakhs on average annually for waste collection and management of the city. The company provide municipal service and also a collection of wastes from households and commercial areas. The company collects a minimum of NRs 100 per month from service takers and the collection fee varies depending upon the type of service taker such as household, commercial, business.

The city lacks a transfer station, and the waste is directly transported to the dumping site located in Ward 21, Amlekhgunj. The location is found near to waterway (river) and forest on the south-east part of east-west highway. At the dumping site, waste is piled up daily, and the company conducts recycling activities; however, the amount recycled is relatively low, accounting for only 15-20% of the total waste collected. There is an urgent need for a proper sanitary landfill and effective waste management in JSSMC. Identifying and allocating adequate land for landfill sites is crucial for sustainable waste management. The

existing dumping site has an area of 1.5 ha. JSSMC has plans to construct and build sanitary landfill sites in place appropriate socially, environmentally and technically in future.

The reliance on private sector involvement for waste management in JSSMC reflects a growing trend in developing countries, where municipalities often lack the capacity to manage waste independently (Zurbrugg, 2002). However, the absence of a transfer station and the direct transportation of waste to a dumping site pose significant environmental and health risks, particularly due to the proximity to waterways and forests. This aligns with findings by Kumar et al. (2009), who emphasize the need for intermediate waste treatment facilities to reduce the burden on landfills. The low recycling rate (15-20%) highlights the need for improved waste segregation and recycling infrastructure, as seen in successful models like Kerala's decentralized waste management system (Narayana, 2009). The planned construction of a sanitary landfill is a positive step, but its success will depend on community engagement and adherence to environmental standards (Wilson et al., 2015).

3.4 Capacity for Waste Management

The Local Government Operation Act of Nepal 2017 assigns municipalities a significant role in managing urban waste. However, the capacity of municipalities to handle and manage waste varies widely due to differences in institutional frameworks and organizational structures. JSSMC have separate divisions to look after waste management. Environment and Disaster Management Division has three subdivisions; Environment and Greenery Promotion, Environment and Climate and Water and Sanitation where the latter one is responsible for SWM.

Table-2: ***Human resources engaged in waste management***

Human resources	**Number**
Environment Engineer	1 (Municipality)
Supervisor	1 (Green and Clean City Pvt. Ltd.)
Driver	3 (Municipality)
Sweepers	17 (Green and Clean City Pvt. Ltd.)

In JSSMC, the human resources with having engineering background recruited was an environmental engineer. The survey identified a shortage of technical human resources in JSSMC for effective waste management. The technical human resources such as civil and mechanical engineers and monitoring and inspection officer such as environmental inspectors are lacking (Table 2). Among others, the sweepers accounted highest figure in JSSMC. Female workers were predominantly found in lower-level roles, primarily involved in city sanitation tasks such as sweeping and cleaning. In terms of gender distribution, males outnumbered females across all positions.

The annual expenditures of JSSMC over three consecutive years were Rs 77 lakhs in the fiscal years 2075/76 and 2078/77, but decreased to Rs 70 lakhs in the fiscal year 2077/78

(Table 3). The annual expenditures of the municipalities remain constant over two fiscal years while reduced in recent years due to the cutoff of the budget due to the COVID19 pandemic. JSSMC financed its waste management through multiple sources, with a substantial portion of its resources derived from the federal government. However, revenue generated from other sources remained limited. No revenue was collected by the municipality as the waste management was done by the private company which collects a minimum of NRs 100 per month from the service taker and the collection fee varies depending upon the type of service taker. In addition to the amount provided by JSSMC to the company, it also uses the collected fees for human resources management and other service delivery.

Table-3: ***Annual expenditure on waste management for the last three fiscal years***

Fiscal year	**Cost of waste management (USD)**	**Revenue from waste collection**
2020/21	63636.36	0
2019/20	70000	0
2018/19	70000	0

The shortage of technical human resources in JSSMC is a common challenge in developing countries, where waste management is often underprioritized in municipal budgets (Zurbrugg, 2002). The gender disparity in waste management roles, with women predominantly in lower-level positions, reflects broader societal inequalities and highlights the need for inclusive policies (UN-Habitat, 2010). The reduction in waste management expenditures due to the COVID-19 pandemic is concerning, as it may lead to decreased service quality and increased environmental pollution. This aligns with global trends, where the pandemic has disrupted waste management systems, particularly in low-income countries (UNDP, 2020). The reliance on federal funding and limited revenue generation from waste collection fees underscores the need for innovative financing mechanisms, such as public-private partnerships and community-based waste management models (Wilson et al., 2015).

4. Conclusion and Recommendations

JSSMC has a population of more than 119,369 in 2021. About 15000 people are living in urban areas. The current annual waste generation is 5445.8 tons/year. With the current growth of population, the solid waste generation in JSSMC is likely to increase in future. This highlights the need for the development of a proper sanitary landfill site to ensure the effective management of municipal solid waste.

Development of sanitary landfills ought to be aligned with present and plans, verified, and more importantly, considering the 20-year planning period. The plan should include land use strategies, road enhancement plans, and forecasts for the expansion of industrial,

commercial, demolition, and construction activities, driven by the ongoing urbanization of JSSMC. Localization of the federal environment protection legal instruments to include solid waste management issues and implementing the "Polluters Pay" principle, alongside enforcing penalties, fines, sanctions, or even shutting down polluting establishments, will play a key role in keeping the city clean and protecting public health. Moreover, preventing and managing hazardous healthcare waste from hospitals and toxic industrial waste will be crucial for safeguarding the health of the city's inhabitants.

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