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Towards Sustainable Solid Waste Management in Kashmir Himalaya: Insights into Household Practices, Challenges, and Opportunities for Resource Recovery

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Abstract

Urbanization and economic growth have led to a substantial increase in waste generation, posing significant environmental and public health challenges. This study focuses on household waste disposal practices, women's roles, behavioral shifts, and challenges for sustainable waste management in Shopian district of Kashmir Himalaya. A systematic random sampling approach was employed to select 352 households across three zones with equal representation. Data were collected using a structured questionnaire applying Delphi method and content valuation process. The findings reveal that the average daily per capita solid waste generation (dry) ranged from 0.25 kg (fringed rural zone) to 0.36 kg (urban zone), with a mean values of 0.30 kg/capita. 66 % waste comprised of compostable organic material, while as 24% was recyclable and 10% was inert, underscoring a considerable potential for resource recovery. Despite this potential, 79% of respondents were reluctant to adopt composting, citing barriers such as lack of awareness, insufficient interest, limited land availability, and inadequate space for waste segregation. Waste management practices vary across zones; urban areas primarily rely on municipal systems, while more than 61% of waste in transitional rural zones and 53% in fringed rural zones are disposed of through unscientific and unauthorized open dumping. Women played a more prominent role in waste disposal compared to men for disposal of household waste. The study recommends a multifaceted approach to mitigate waste generation, enhance recycling and reuse, minimize open dumping and landfilling, and promote community engagement and behavioral change. These strategies are essential for achieving sustainable waste management and conserving resources, thereby fostering a transition towards a circular economy.

Keywords: *Solid waste, Waste management, Environmental education, Recycling, Sustainability, Public awareness*

Introduction

The management of solid waste has appeared as a critical global issue, encompassing environmental, economic, and social dimensions. The rapid increase in human population, coupled with urbanization, industrialization, and economic growth, has led to a considerable rise in waste production worldwide (Coelho & Lange, 2018; Yao *et al*., 2019; Ajibade*et al*., 2021; Voukkali *et al*., 2023). This situation is particularly well-defined in developing and underdeveloped countries, where inadequate infrastructure and improper and unauthorized waste disposal practices contribute to severe environmental as well as health consequences (Singh *et al*., 2022; Mor & Ravindra, 2023). The generation of solid waste is determined by various factors, including population growth, economic affluence, contemporary throwaway lifestyles, and waste-generating technologies (Kolekar *et al*., 2017; Tomic and Schneider, 2018; Chew *et al*., 2019; Kumari & Raghubanshi, 2023; Mor & Ravindra, 2023).

The need for effective Solid Waste Management (SWM) is underscored by the

alarming projections: global generation of municipal solid waste (MSW) is expected to escalate from 2.1 billion tonnes in 2023 to 3.8 billion tonnes by 2050 (UNEP, 2024). The challenges are further compounded by varying waste generation rates across different income groups and regions, with high-income nations encountering a slower growth in waste production compared to low- and middle-income countries (Chandrappa & Das, 2024). This disparity highlights the necessity of context-specific strategies in addressing SWM issues.

On average, worldwide per capita per day waste generation is 0.74 kilograms, ranging from 0.11 to 4.54 kilograms (World Bank Report, 2023). In underdeveloped countries, the situation is exacerbated by unplanned and spontaneous human settlements and broad industrial establishments, which contribute significantly to environmental pollution. Countries like India, Bangladesh, Indonesia, Vietnam, Sudan, Malaysia, and Ethiopia are some of the leading contributors to solid waste production among underdeveloped nations (Dhokhikah & Trihadiningrum, 2012; Kumar *et al*., 2023). As per the report by The Energy and Resources Institute (TERI), in India over 62 million tonnes (MT) of waste is generated annually, with the Indian Central Pollution Control Board (CPCB) projecting this to increase to 165 MT by 2030.

Management of vast quantities of municipal solid waste can pose a significant challenge to the entire world, mainly in developing countries (Nosheen *et al*., 2022; Alwan& Ismael, 2023; Aziz *et al.,* 2023). Until now, the significant fraction of municipal solid waste generated remains untreated and is still landfilled. In developing countries landfilling and dumping represents the only practicable option for final waste disposal (Munawar & Fellner, 2017). Landfilling is the most prevalent and extensive method of waste disposal in underdeveloped and developing countries because of its cost-effectiveness. Globally, 37% of Municipal Solid Waste is disposed off in landfills (8% is inclined towards sanitary landfill, 4% in controlled landfill, and 25% is unspecified) (Amin *et al.,* 2023).In India, approximately 82% of Municipal Solid Waste is collected and the remaining 18% is litter. The waste treated is only 28% of the collected waste, and the remaining 72% is openly dumped (Sharma & Jain, 2019).

Moreover, the management and treatment of waste, particularly MSW, engross significant considerations like composition as well as the characteristics of waste materials. These factors not only drive emissions during waste processing and disposal but also determine the potential for resource recovery and recycling (Pecorini & Iannelli, 2020; Hettiaratchi*et al*., 2021; Nanda & Berruti, 2021; Hoang *et al*., 2022). Management of waste refers to the controlled organization of waste generation, storage, collection, transfer, processing, and disposal (Ravichandran & Venkatesan, 2021; Mohanty *et al*., 2022). It includes technologies intended at harnessing energy from waste materials, with a significant focus on managing municipal solid waste (MSW) (Khan *et al*., 2022; Traven, 2023; Thilagasree *et al*., 2024). Despite this, a considerable proportion of waste is

either openly discarded or disposed off in landfills (Ameen *et al*., 2023). These management practices create serious environmental hazards including groundwater contamination, water, soil and air contamination, health hazards, and aesthetic damage, loss of biodiversity, plus the exhaustion of natural as well as economic resources (Singh *et al*., 2022; Mor & Ravindra, 2023).

The role of socioeconomic factors, community behavior, and public awareness and consciousness in waste management cannot be overlooked. Studies point out that effective SWM requires active participation from residents, with particular prominence on the role of women in waste reduction and recycling (Keser *et al*., 2012; Jusoh *et al*., 2018; Zoroufchi *et al*., 2019; Noufal *et al*., 2020; Zhao *et al*., 2021). This participation includes activities such as reducing, sorting, reusing, and recycling waste (Ghazali *et al*., 2021; Mukherjee *et al*., 2023). Various policy instruments have been projected to encourage proper waste management behaviors (Seadon, 2006; Puntillo, 2023). Community knowledge, attitudes, and practices concerning proper waste management are also crucial (Babaei*et al*., 2015; Koderi*et al*., 2018; Almasi*et al*., 2019; Limon &Villarino, 2020; Loan *et al*., 2023). Effective household waste management requires awareness and sensitivity to sustainable environmental practices from both men as well as women (Wut *et al*., 2021; Shahzad *et al*., 2022; Bala & Sharma, 2023).

In many regions, women play an outstanding role in waste reduction and reuse, often being accountable for cleanliness and hygiene around homes and neighborhoods (Zand *et al*., 2020; Elsheekh *et al*., 2021). In many countries, women are prominently involved in recycling activities, such as picking recyclables from municipal waste, dumpsites, or landfills (Muhammad & Manu, 2013). Women can organize entire communities for waste management activities, thereby strengthening social cohesion (Singh *et al*., 2022). Studies have shown that housewives significantly contribute to reducing and recycling household waste, influencing household waste management behaviors (Muhammad & Manu, 2013; Hadiningrat, 2020; Mwangi & Waweru, 2024).

In India, the current approach to SWM remains largely unscientific, with ample portions of waste being randomly dumped without proper treatment (Nandan *et al*., 2017; Das, 2020; Mohanty *et al*., 2022; Meena *et al*., 2023). This not only intensifies environmental degradation but also poses significant challenges to sustainable waste management efforts (Das, 2020; Kumar & Agrawal, 2020). The inadequacies in planning, management, and enforcement of waste management regulations further complicate the scenario. Given these challenges, this study seeks to address these critical gaps by (i) investigating existing waste management and disposal practices (ii) Assessing public perception, behaviour, and awareness regarding waste management (iii) Identifying challenges and opportunities for

recycling, composting, and resource conservation.

Materials and Methods

Study area

In order to characterize scenario of solid waste and subsequently find ways to manage it properly, the study was conducted in Shopian, the southern part of Kashmir Valley, located in the Indian Union Territory of Jammu and Kashmir because of its varied socio demographic characteristics. The study area has been divided into three categories that form a representative of a Himalayan area with an urban area, a rural area and a far-flung area. These three areas have differences in their socio-cultural dimensions. Overall, this district is known as the "Apple Town of Kashmir" situated on the historical Mughal Road with most of its area occupied by forests and is famous for the "Hirpora wildlife sanctuary". This place comes under the PirPanjal Range which makes it very cold in winter, where temperature often drops to as low as -7°C. The district is subdivided into 2 blocks (Shopian and Keller) having population of 266,215. The population density of the municipal area is 852 persons per km^2 as per 2011 Census Report (Census, 2011, Wikipedia).

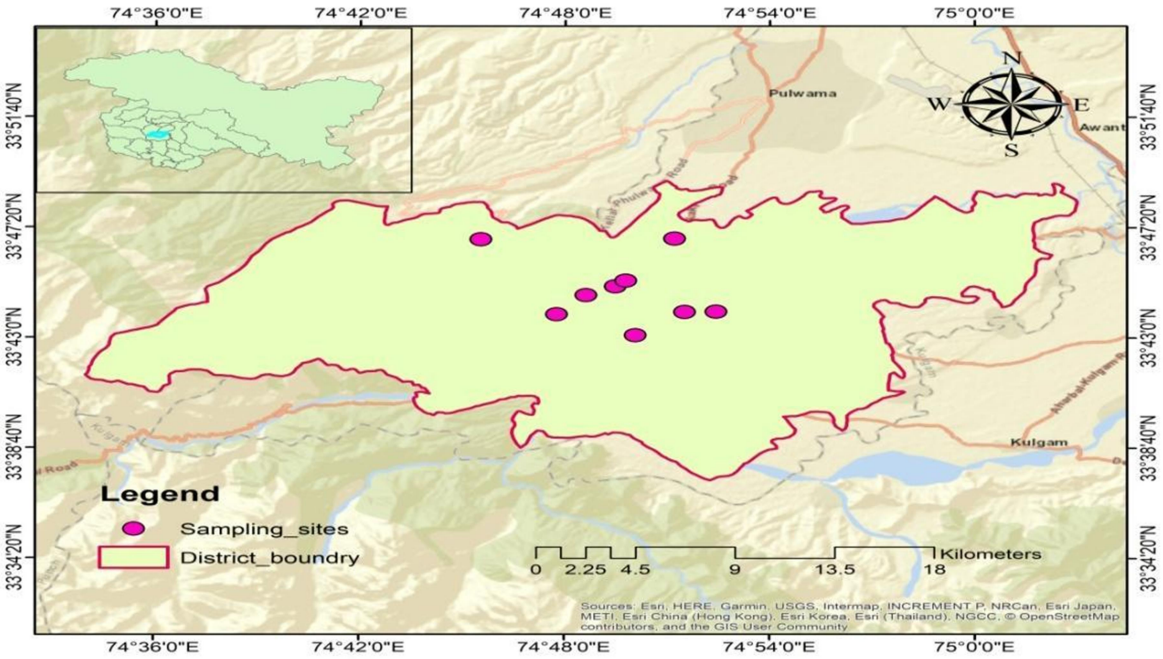


Fig. 1: The geographical location of the study sites

Table 1: Household selection for the study

Area	Sites	Number of Households	Description
Zone 1	Central Urban Zone	118	This zone is characterized with most of the socio demographic activities like commerce, trade, traffic and urban local bodies of management.
Zone 2	Transitional Rural Zone	117	This zone surrounds the central zone and offers an intermediate activity with a mixed urban and pristine rural culture
Zone 3	Fringed Rural Zone	117	This zone is the marginal pristine zone that hasn't been explored in terms of ecological preservance and sustainability. This zone is characterized mostly by low-income households and lack in most of the basic modern-day facilities.

Statement development process:

To begin with, a significant number of indicators/statements were chosen from the accessible sources on solid waste management. Most studies have modeled a large list of sector-specific indicators/statements. The approach begins with a setup developed from several sources in order to find out the ones that appear best suited towards framing solutions to the problems. Individual semi-structured interviews with main stakeholders are carried out to capture the diverse opinions in order to put in some additional indicators/statements. The Delphi Method was adopted to evaluate the indicators' suitability (Veysi *et al.,* 2019). Following the opinions and suggestions, this study adopted a 3-round Delphi to estimate potential indicators on a 5-point Likert Scale. Before heading towards the three rounds, the panelists were asked to comment on the preliminary list's format, its language, and content validity. A Content Validation Ratio (CVR) was executed to confirm the validity of indicators. From the three repeated /consecutive rounds of Delphi method, 35 indicators were lastly retained.

Indicator validation process

Lawshe's Content Validation Ratio (CVR), is one of the most comprehensive and advanced approaches for carrying out and determine the content validation (Almanasreh *et al.,* 2019). The first two and last two points of the Likert scale were combined, then the CVR was calculated as:

$$CVR = \frac{n_e - (\frac{N}{2})}{\frac{N}{2}}$$

Where n_e is the actual number of experts representing the indicator that happens to be essential and N is the total number or figure of experts in the panel.

Furthermore, Cronbach's Alpha was also used to find out the internal consistency of the data.

Cronbach's Alpha (α):

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum \quad s^2y}{s^2x}\right]$$

Where k is the number of test items (indicators), $\sum \quad s^2y$ is the sum of the item variance and s^2x is the variance of the total score.

Description of the experts' panel

As recommended by (Musa *et al.,* 2019) , the minimum size of panel should be seven or eight, in order to be appropriate for the Delphi study, and 20 to 60 participants are required (Diamond *et al.,* 2014 and Hardie *et al.,* 2022) for the speckled group (expertise/proficiency on a topic). In the round first, 20 stakeholders of different backgrounds or expertise in academics with different expertise in academics like waste management, local knowledge, planning, etc. were interviewed. In the second and third rounds, 15 stakeholders were willing to participate and 5 refused because of their personal or unmentioned reasons.

Table 2. Expert background

Expert Background	Round one	Round two	Round three
Academicians	6	4	4
Govt. officials and municipal committee members	5	3	3
NGO's	4	3	3
Local People	5	5	5

Fig.2

Fig. 3

Fig. 2 and Fig. 3 represent carrying out an interview and survey of various experts.

Sample survey:

From each cluster, 1000 households were selected, totaling 3000 households overall. From this population, a sample size was taken and evenly distributed among each cluster.

Yamane's formula (Rahman *et al.,* 2020) for calculation of sample size is the best representation and was adopted to determine the sample size i.e., 352 Household respondents.

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

Where; N = the total population that will be studied

n = the required sample size

e = the precision level 0.05 at the confidence level of 95%

Delphi exercise rounds:

Table 3.Delphi exercise rounds

Delphi Exercise	Number of items evaluated/ retained	Number of stakeholders involved	Response Rate	No. of Indicators Exempted
Delphi Round I	-firstly, 28 indicators had been sent to various stakeholders -18 indicators having CVR *≥0.42* had been retained *(Almanasreh et al., 2019)*	20 stakeholders had been invited to engage at this level and all responded	*100%*	*Ten*
Delphi Round II	-18 indicators had been sent to stakeholders -13 indicators having CVR ≥0*.42* had been retained (*Almanasreh et al., 2019)*	*20* stakeholders had been invited and only *15* responded	*75%*	*Five*
Delphi Round III	-13 indicators had been sent to stakeholders -All of them were retained as their CVR scores had been *≥0.49* (*Almanasreh et al., 2019)*	*15* stakeholders had been invited and all responded	*100%*	

Delphi final round indicators/statements:

Table 4. Delphi final round indicators/statements

Statements/Indicators	Not essential	Important but not essential	Essential	CVR
How often do you generate solid waste?	2	1	12	0.60
Do you segregate your waste into different categories (e.g., organic, recyclables, non-recyclables)?	1	1	13	0.73
If there is a regular waste collection service/ facility in your area?	0	2	13	0.73
How frequently is waste collected from your household?	1	1	13	0.73
Do you have separate bins or containers for different types of waste?	2	1	12	0.60
If yes, how many types of waste do you segregate at home?	1	1	13	0.73
Do you recycle any materials at home?	2	1	12	0.60
If yes, which of the following materials do you recycle?	1	0	14	0.86
Where do you dispose of your non-recyclable waste	1	1	13	0.73
How satisfied are you with the waste disposal facilities available to you?	0	3	12	0.60
Have you received any education or information on proper waste management practices?	0	2	13	0.73
Do you actively try to reduce waste generation at home?	2	1	12	0.60
What are the main challenges you face in managing your household waste?	1	0	14	0.86

Solid waste generation and composition at residential areas

To achieve a consistent sample characterization, a waste protocol was adapted from the Environmental Protection Agency (1994) which covered components like waste generation, sampling and sorting, frequency and seasonality to enable assessment of the impact on waste stream characteristics. A total of 15 samples of MSW, 5 each from each sampling zone viz., central zone, transitional zone and far-flung zone were collected, sorted, categorized, weighed and documented for four (04) seasons. During each sampling the amount of waste generated in a household for twenty four hours was collected and put in a polythene bag with a capacity of 10 kg, consecutively for a period of 7 days (Ojeda-Benitez *et al.,* 2013; Mir & Rampal, 2017; Jedrczak *et al.,* 2023). Collected samples were initially weighed with the help of digital balance to determine the overall weight of the sample and then segregated into different components manually and categorized as per the Municipal Solid Waste Management Rules, 2016. Both the qualitative as well as the quantitative compositions of biodegradable,

non-biodegradable wastes were also evaluated. Equation (1) and (2) were employed in order to find out the waste generation in terms of kg/day and kg/capita/day and Equation (3) was used for calculation of composition of waste (percentage).

$$Generation\ (kg/HH/day)\ G\ = \frac{TotalMSWcollected}{Numberofsamplingdays} \quad \textbf{(1)}$$

Generation per capita (kg/cap/day) Gp =G/ Nr **(2)**

Where Nr is the number of persons living in a household

The composition of waste in percentage, % = mass of each component of waste (kg)/ total mass of collected waste (kg) × 100 **(3)**

Laboratory analysis

For the analysis, triplicate samples were analyzed for moisture content, for determining net weight composition (%) and net weight (Kg) or dried weight (Kg). The moisture content of the samples was determined after drying the waste material at 105°C for 24 hours and expressed as a percentage of total weight (Nirmaan *et al.,* 2020) as per the formulae given below.

$$Netweightcomposition\ (\%) = \frac{Weight\ of constituent\ of\ solidwaste}{Total\ weight\ of constituents}\ x\ 100$$

Per capita net weight (kg/person/day) was calculated and determined by dividing the net weight of constituents of municipal solid waste generated (kg) to the number of persons residing in each household of the study area.

Results and Discussion

Socio-demographic characteristics:

Table 5. Socioeconomic characteristics of the responding households

Socio-demographic variables	Category	Frequency (N)	Percentage (%)
Gender (N = 352)	Male	164	47
	Female	188	53
Age (N = 352)	≤ 19	3	0.85
	20-29	20	5.68
	30-39	53	15.06
	40-49	96	27.28
	50-59	115	32.67
	≥ 60	65	18.46
Educational status (N = 352)	Illiterate	110	31
	literate	242	69
Household size (N = 352)	Below 5	212	60
	Above 5	140	40
Monthly income (N = 352)	≤ Rs 15000	147	42
	15000-35000	112	32
	35000-50000	72	20
	≥ 50,000	21	6

Income, gender and education status are a few of the social-economic factors that influence waste generation and the management practices and is an primary step to understand the household waste distinctiveness before introducing and adapting a new stratagem for waste management **(**Sultana *et al.,* 2021; Coronel-Chugden *et al.,* 2023). In the present study 53% were female and 47% were male respondents representing mostly nuclear households. The family size and income levels are given in Table 6.

Table 6. Questionnaire data analysis

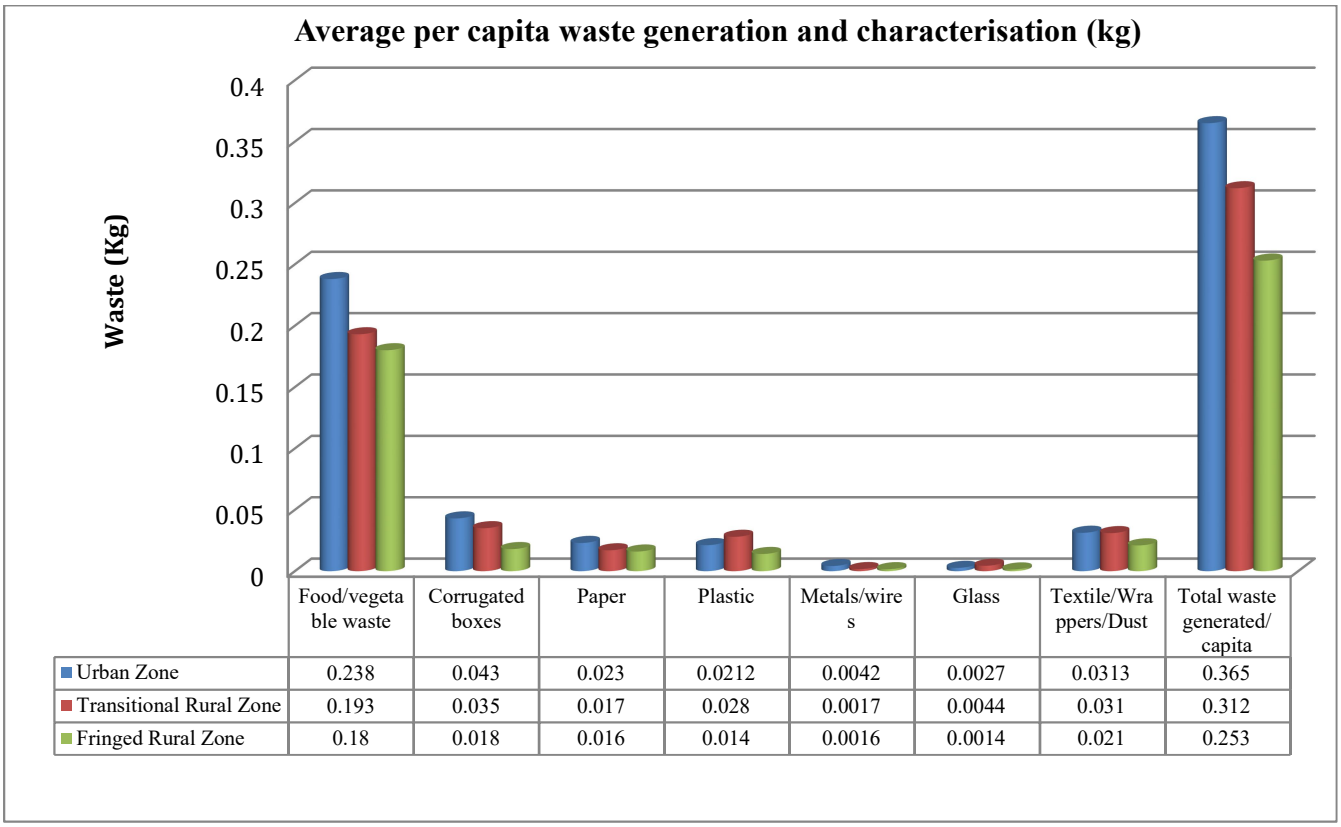
Waste Characteristics Questions			Central Urban zone	Transitional Rural Zone	Fringed Rural Zone
Waste Collection Service	Are there any regular waste collection facility/ service in the area?	1. Yes	118 (100%)	0	0
		2. No	-	117(100%)	117(100%)
	If not, are you willing to pay to the Municipal Council for management of the waste at home?	1.Willing	-	45 (38%)	52 (44%)
		2.Non willing	-	72 (62%)	65 (56%)
Waste Segregation by householder (Women)	Do you segregate your waste into different categories (e.g., organic, recyclables, recyclables)?	1. Yes, always	30 (25%)	49 (42%)	41 (35 %)
		2. No, Never	88 (75%)	68 (58%)	76 (65%)
	If not, are you willing to start waste segregation at household level?	1.Yes	4 (5%)	35 (52%)	34 (45%)
		2.No	84 (95%)	33 (48%)	42 (55%)
Waste Recycling	Do you recycle any materials at home?	1. Yes	62 (53%)	64 (55%)	63 (54%)
		2. No	56 (47%)	53 (45%)	54 (46%)
Waste Disposal	Where do you dispose of your HH waste?	1.Take it to secondary storage community bin	-	1 (<1%)	6 (5%)
		2.Dumping in the pit around home	-	12 (10%)	8 (7%)
		3.Open space dumping	-	22 (19%)	30 (25%)
		4.Dumping in waterways	-	10 (9%)	9 (8%)
		5.Through burning	-	-	2 (<2%)
		6.Managed by Municipal Services	118 (100%)	-	-
		7. Multiple ways of unauthorized	-	72 (61%)	62 (53%)

		disposal			
	Who actually dumps the waste?	1.Male	2	14	4
		2.Female	100	73	73
		3.Either male/female	16	30	40
Attitude towards HH waste composting	Willingness to compost HH waste?	1.Willing	2 (<2%)	38 (32%)	40 (34%)
		2. Non willing	116 (92%)	79 (68%)	77 (66%)
	Hindrances for being unwilling to start the composting?	1.Lack of land for composting	4 (3%)	6 (8%)	1 (<1%)
		2.Lack of awareness regarding composting	10 (9%)	31 (39%)	20 (26%)
		3.Having enough space to dispose of the waste	6 (5%)	12 (15%)	24 (31%)
		4.Not interested	82 (71%)	21 (27%)	26 (34%)
		5.Multiple hindrances (above mentioned hindrances together)	14 (12%)	9 (11%)	6 (8%)
Awareness	In your opinion is solid waste a major problem?	1. Yes	98 (83%)	88 (75%)	94 (80%)
		2. No	20 (17%)	29 (25%)	23 (20%)
Challenges	What are the main challenges you face in managing your household waste?	1.Lack of awareness about proper waste management	17 (14%)	14 (12%)	31 (27%)
		2.Limited space for waste storage	7 (6%)	11 (9%)	1 (<1%)
		3.Lack of facility and proper waste collection service	10 (9%)	12 (10%)	21 (18%)
		4. Lack of interest	54 (45%)	62 (53%)	54 (46%)
		5.Multiple mixed hindrances (above mentioned hindrances together)	30 (25%)	18 (16%)	10 (8%)

Waste generation and characterization

For quantitative analysis, the generation amount and composition of solid waste from 15 households, (5 households from each zone, for a period of 7 days in) were recorded on a seasonal basis. The average and the per capita waste generation (on dry weight basis), in all the three zones are given in Fig.4. The findings revealed that the average daily per capita solid waste generation (dry) ranged from 0.25 kg (fringed rural zone) to 0.36 kg (urban zone),

with a mean values of 0.30 kg/capita. As per the central pollution control board (CPCB) of India, the per capita waste generation has increased at an exponential rate (0.26 kg/day to 0.85 kg/day) from the year 2001 to 2018 (Kumar *et al.,* 2017; CPCB India, 2018). The CPCB report indicated that the solid waste production rate lies between 200 and 300 g/capita/day in small towns/cities with populations less than 0.2 million. It is usually 300–350, 350–400, and 400–600 g/capita/day in cities with population ranges of 200,000–500,000, 500,000–1 million, and above 1 million, respectively (CPCB, 2016; CPHEEO, 2016; MNRE, 2016). The higher per capita waste generation may be attributed to the factors like household size i.e, larger the household, higher will be the waste generation (Senzige e*t al.,* 2014; Suthar & Singh, 2015; Trang *et al.,* 2017; Khan *et al.,* 2022), income i.e. high income household's tend to generate more waste (Medina, 1997 and Zhu *et al.,* 2013), lifestyle, geography, dietary habits, and socioeconomic status (Enayetullah *et al.,* 2005; Hoornweg & Bhada-Tata, 2015).



	Food/vegetable waste	Corrugated boxes	Paper	Plastic	Metals/wires	Glass	Textile/Wrappers/Dust	Total waste generated/ capita
Urban Zone	0.238	0.043	0.023	0.0212	0.0042	0.0027	0.0313	0.365
Transitional Rural Zone	0.193	0.035	0.017	0.028	0.0017	0.0044	0.031	0.312
Fringed Rural Zone	0.18	0.018	0.016	0.014	0.0016	0.0014	0.021	0.253

Fig.4. Average (per capita) waste generation and characterization.

Since, the solid waste is heterogeneous in nature, this study found 66% of this waste being compostable organic food and vegetable waste, while the remaining 34% of waste consists of materials mainly corrugated boxes (10%), textiles, dust and inert matter (9%),

plastics (7%), paper (6%), metals and beverage cans (<1%) (Fig.5). From the total waste, other than compostable organic waste, 24% was recyclable and 10% was inert, underscoring a considerable potential for resource recovery from the study area (Fig. 6). Municipal solid waste composition in India is approximately 40–60% compostable, 30–50% inert, and 10–30% recyclable (Gupta *et al.,* 2015). The composition of Indian solid waste mostly contains the organic substance with high moisture content. The higher composition of biodegradable waste may be attributed to less usage of packaged products in the region than the other high income regions (Alfthan *et al.,* 2016). Kumar *et al.,* 2016, carried out a study on waste composition for high-altitude subtropical regions across Indian Himalayan Region, highlighted the biodegradable waste was 54.83% followed by inert, ash, and debris waste (21.06%), paper (8.77%), plastic (8.18%), glass and ceramics (4.45%), and metal (2.71%). However, the data from Joshi & Ahmed (2016) reported 52% of the waste as biodegradable followed by paper (14%), rubber (8%), metals (1.5%), glass (1%), inerts (23%), and rags (<1%).

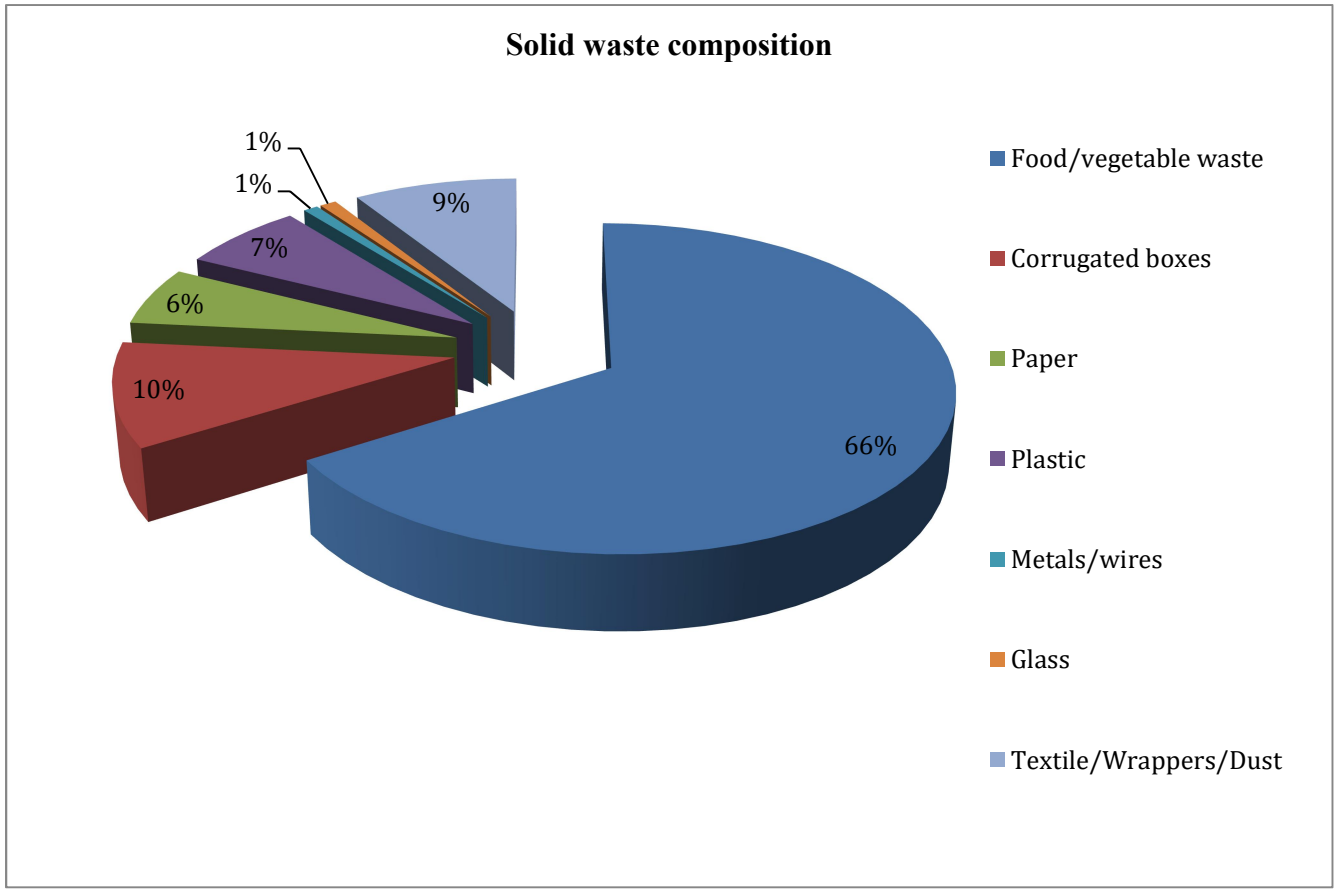


Fig. 5. Overall composition of household solid waste from the study area

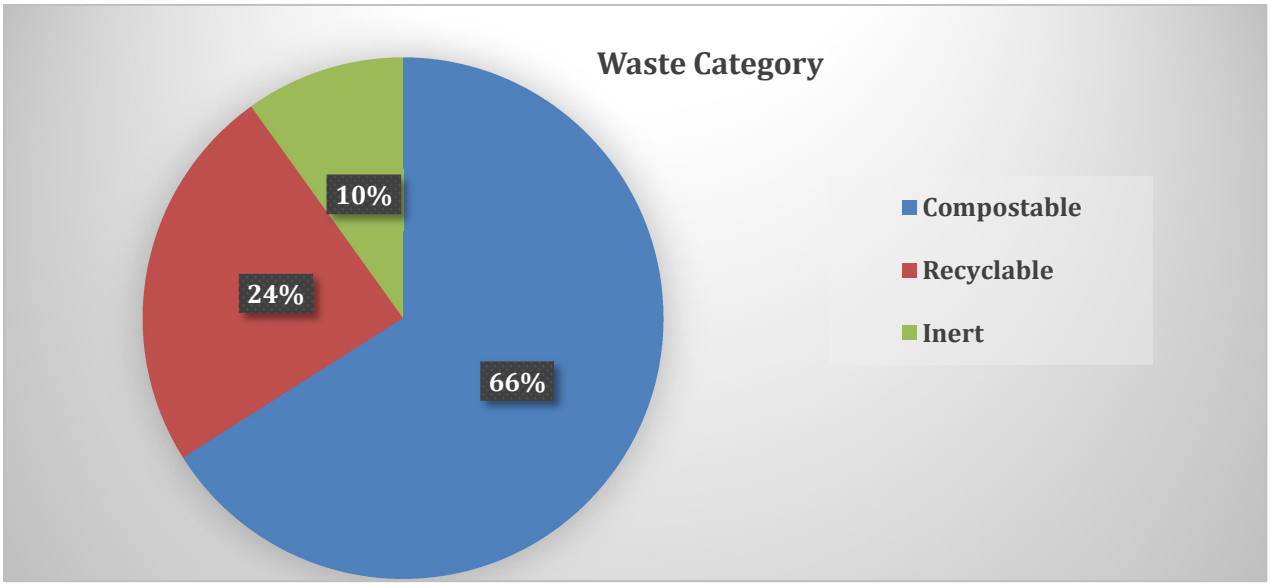


Fig. 6. Overall waste categorization from the study area.

The composition of municipal solid waste (MSW) varies, depending on the inhabitant's local income and consumption patterns. Income is an influential factor directly affecting waste generation, often linked to the consumption of processed and packaged foods and other resources. Our study found that higher-income residents tend to generate more waste, supporting the notion that waste generation is closely related to household income levels. As noted by Medina (1997) and Zhu *et al*. (2013), higher-income families typically consume more products than lower-income families. However, it's important to recognize that education, lifestyle, and cultural background also play significant roles in waste generation and management.

Perception, behaviour and awareness regarding waste management

Perception, behaviour and awareness are the important factors for any successful strategy, management practice and even policy. Perception in waste management refers to how individuals understand waste, its impacts, and the practices for managing it, while as behavior pertains to the actions and habits that individuals adopt in managing waste. In waste management, the key aspects of perception and behavior include source separation, recycling and reusing, knowledge and awareness and attitude, beliefs, and values. Our study showed that 54% of residents were positive towards the waste management having considerable knowledge of the benefits of scientific waste management as well as the drawbacks of unscientific and unauthorized disposal methods. Our results highlight that these respondents were also either paying or were willing to pay for these management activities and thus, contribute to the environmental protection (Zia *et al.,* 2017). Rest of the respondents (46%) with most of them belonging to transitional and fringe rural areas didn't have enough knowledge of these

practices and there co-benefits. The reasons supporting the hindrances in waste management practices are summarized in Fig 7. About 48.3% of the respondents were not interested or showed a lazy approach towards the waste management citing that the solid waste is not a problem. Rest of the responses were mixed with lack of awareness (17.6%), lack of limited space for waste storage (5.4%), lack of proper facilities (12.2%), and multiple/ mixed hindrances (16.5%), as reasons for not being able to drive positive attitude towards scientific solid waste management practices (Agbefe *et al*. 2019). However, when residents in transitional and fringed rural zones were asked about their willingness and keenness to pay for municipal services, only 38% of families in transitional rural zones and 44 % of families in fringed rural zones were positively inclined towards having municipal services.

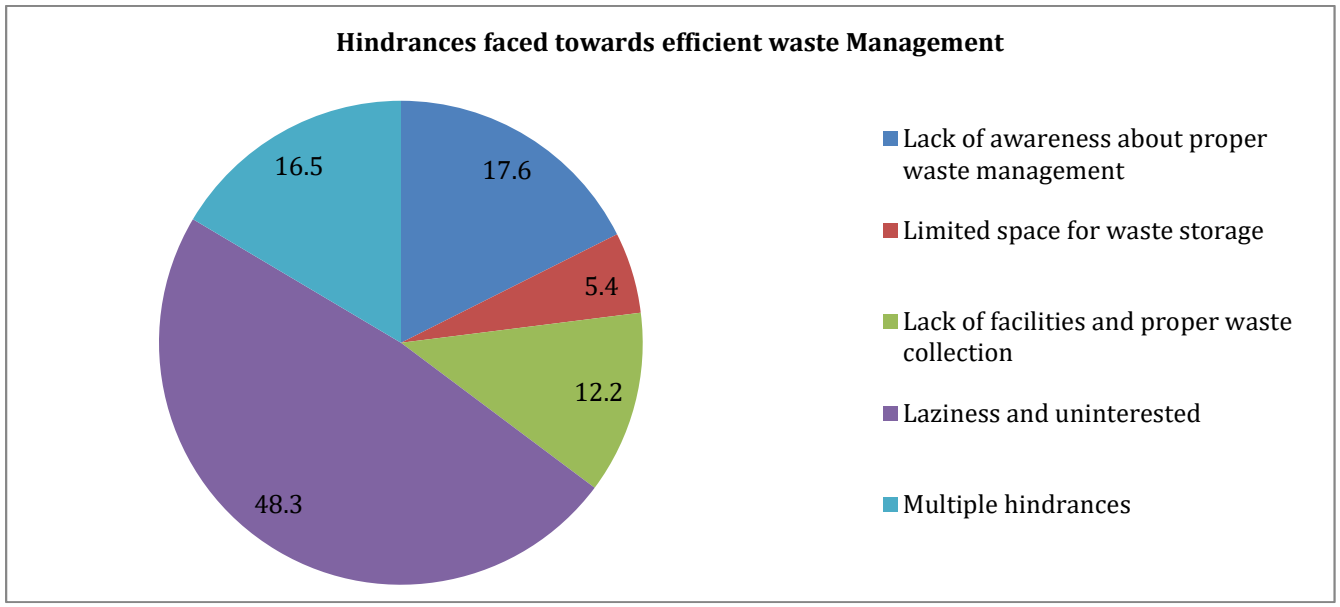


Fig.7. Percentage of the residents who face challenges and hindrances for managing the waste.

Waste management and disposal practices and their implications

Waste management determines the proper collection of waste, its processing along with its final disposal in order to minimize its negative implications. While studying the waste management and disposal methods being practiced in the three areas studied, the waste in the urban area was primarily and fully managed through the services provided by the government local bodies i.e. the Municipal Council. However, in transitional and fringed rural zones, majority of the waste was managed through unscientific and unauthorized practices mainly through open space dumping, water dumping and open burning (Fig. 8). Such waste disposal practices for example, 61.5 % of households in transitional rural zone and 53 % in fringed rural zone cause not only the aesthetic degradation but also result in loss of recyclables having huge economical value. The disposal of recyclables along with other wastes often lead to contamination of soil, water, and

air, thus creating a risk for humans and environment (Zikali *et al.,* 2022).

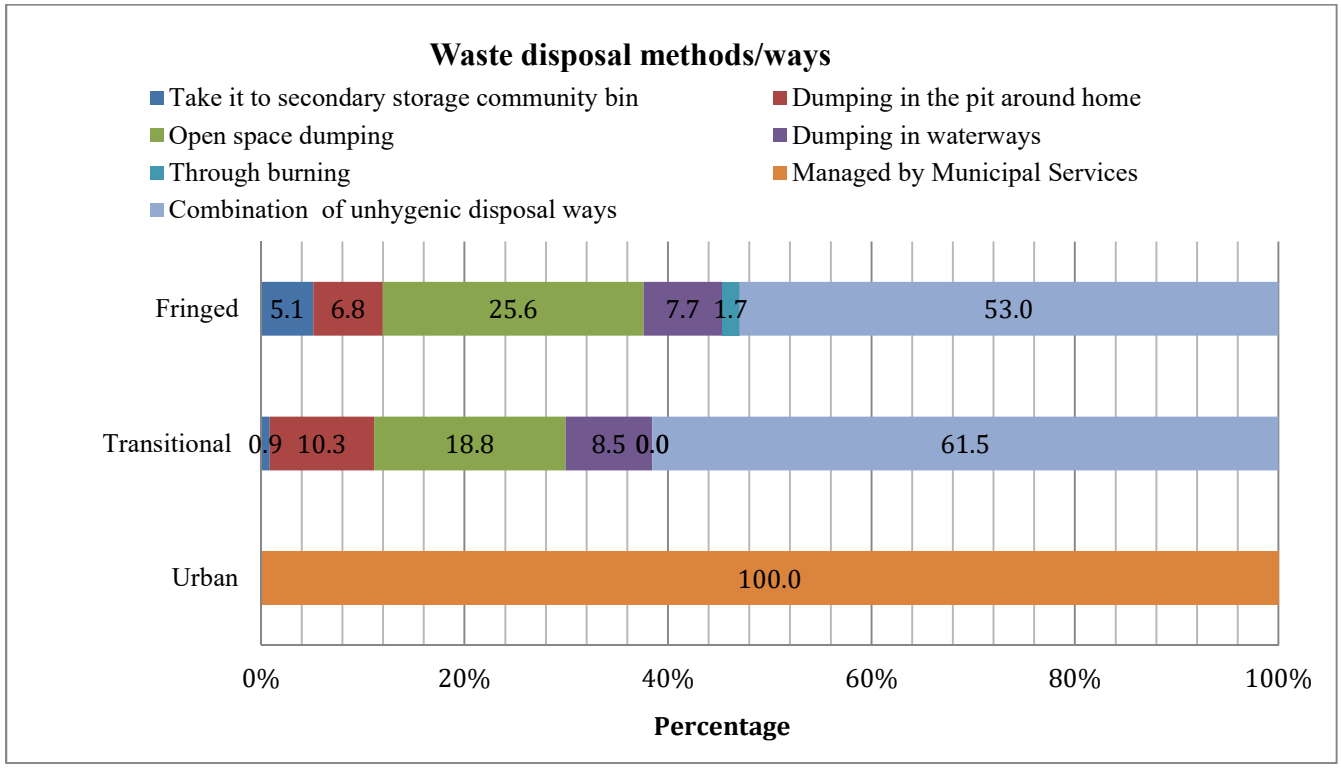


Fig. 8. Percentage of people using different methods of waste disposal or combination of these unhygienic methods.

Role of women in waste management

Women play a significant role in structure and functioning of a society including the solid waste management. Women's inclination towards household activities is influenced by various factors like traditional gender-sensitive approach, cultural norms and socialization can significantly enhance women's contributions towards these activities at the source. In this study, it was found that women (about 70%) were the primarily and actively involved with the waste disposal and management practices. Studies carried out by (Almasi *et al*., 2019; Alhassan *et al*., 2020; Gyimah *et al*., 2021) also highlighted active role of women in waste disposal as compared to men. Despite the higher percentage of women involved in waste management practices, women folk still faced many challenges such as a lack of awareness and information, and the influence of community attitudes and social norms. They emphasized the need for collective community efforts and commitment to manage waste, particularly in rural areas. This study also highlighted, only 34% of women were involved in waste segregation, primarily for feeding the organic portion (vegetable/food waste) to cattle. Of the remaining 66% of women, only 31% were willing to participate in waste

segregation, while the majority (69%) were not inclined towards it (Fig. 9).This may be attributed to a lack of adequate bins for waste separation, insufficient storage space in low-income households, and possibly no outlook towards waste management (Udofia & Fobil, 2018), lack of motivation and awareness (Abushammala & Ghulam, 2022).These reasons prevent the residents from participating in waste management practices like source separation and reusing and recycling initiatives (Noufal *et al*., 2020).

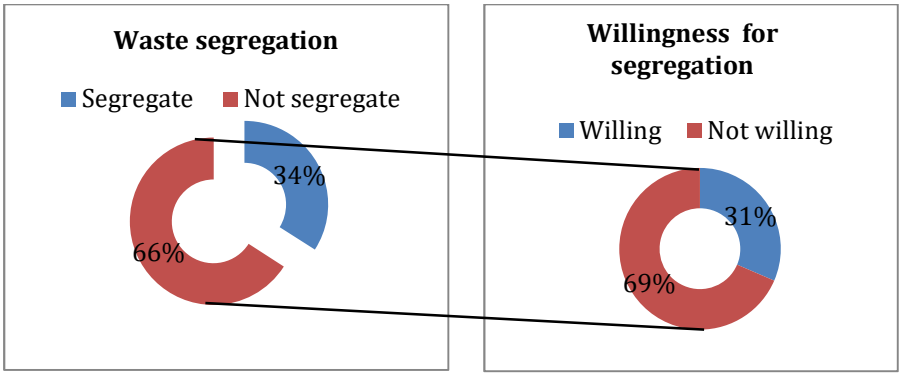
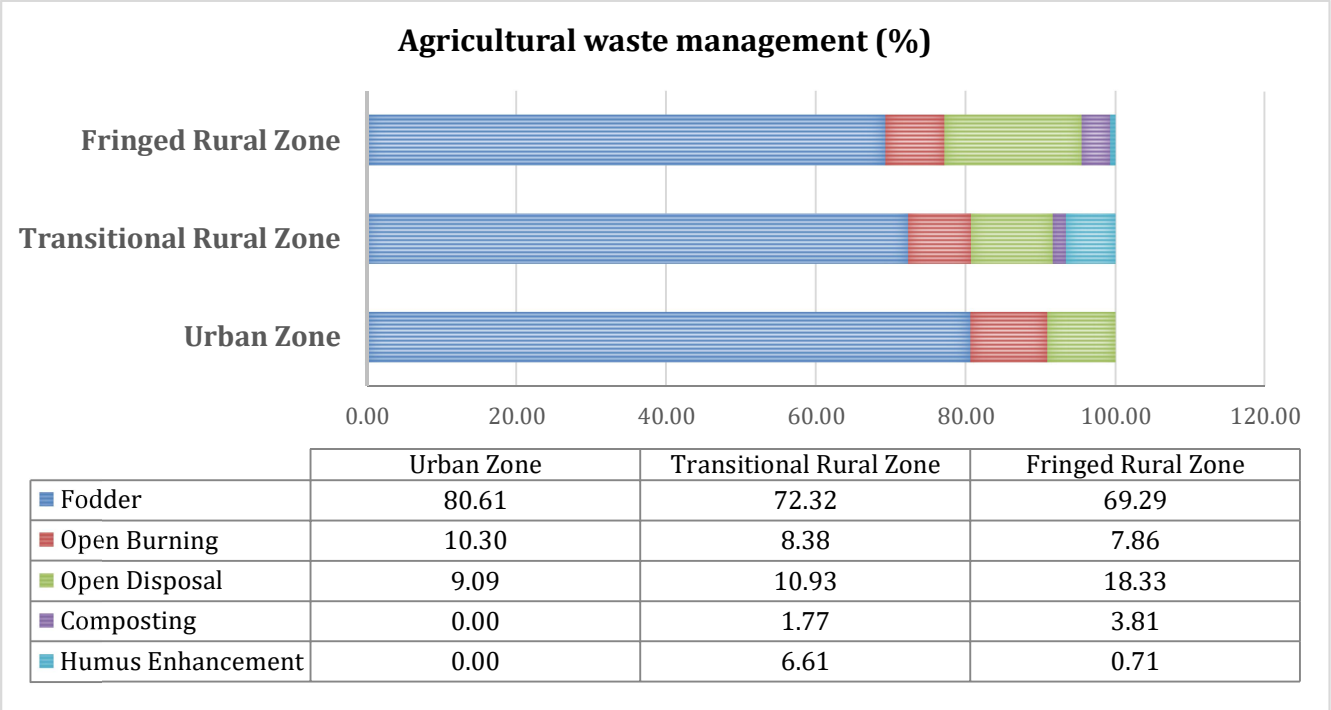


Fig. 9 Willingness of women towards waste segregation

Composting of waste at household level-opportunities and challenges

Given the significant biodegradable portion in household waste, composting is a highly approving method of waste treatment (Guidoni *et al*., 2018). Composting is a natural process that involves microbial succession, resulting in the degradation and stabilization of organic matter in waste. This process plays a fundamental function in recycling organic matter and repairing the environment (Pandey *et al*., 2016). However, there is need to assess the awareness and attitude towards the composting that was taken up in this study. Survey results revealed that nearly half of the residents were familiar with different composting methods, such as composting pits and heaps. Only the agricultural waste was managed through composting comprising of a very little percentage (1.77% in transitional rural zone and 3.81 % in fringed rural zone). Majority of the agricultural waste was used as fodder (70 % to 80%) and the rest was disposed directly in fields for humus enhancement, burned or openly dumped. While assessing the attitude of the respondents to start managing both HH solid waste and agricultural waste through composting (Fig. 10), only 23% of residents agreed to initiate the process. The majority (77%) were unwilling to practice composting because of certain challenges like unawareness, lack of interest, insufficient land, and adequate space for open disposal, as illustrated in Fig. 11. This lack of willingness and interest to manage waste at the source poses a significant concern for environmental policymakers (Birhanu & Berisa, 2015).



	Urban Zone	Transitional Rural Zone	Fringed Rural Zone
Fodder	80.61	72.32	69.29
Open Burning	10.30	8.38	7.86
Open Disposal	9.09	10.93	18.33
Composting	0.00	1.77	3.81
Humus Enhancement	0.00	6.61	0.71

Fig. 10 Management of agricultural waste in various zones

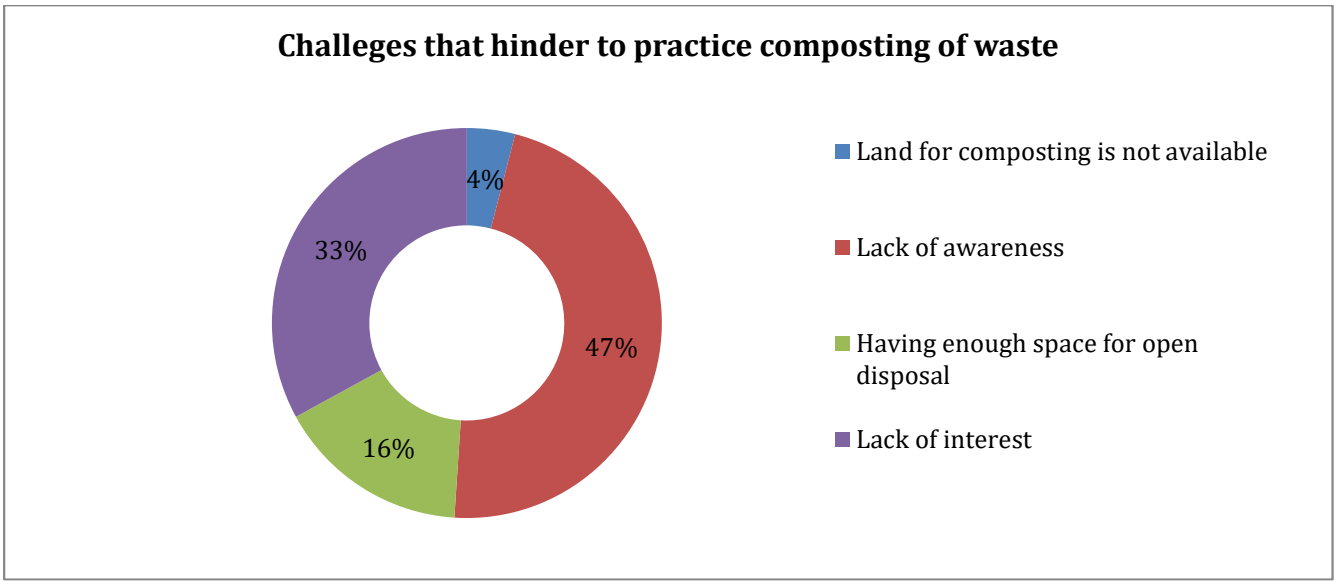


Fig. 11 Percentage of residents facing challenges while starting the composting of waste

Conclusion

The study highlights the critical challenges and opportunities in solid waste management (SWM), illuminating the need and requirement for effective strategies, particularly in urban and rural landscapes. Key conclusions are as follows:

I. *Waste Generation and Composition:* There is a variation in daily per capita waste generation with an average net waste of 300 g/capita/day influenced by socioeconomic factors like income, education, and household size. Organic waste constitutes a major portion, presenting opportunities for composting and resource recovery.

II. *Gender Roles in Waste Management:* Women play a pivotal role in household waste management, particularly in waste segregation and disposal. However, their participation is hindered by factors like lack of awareness, education, and proper facilities.

III. *Community Perception and Behavior:* While some urban residents are aware of and participate in recycling, rural areas show a lack of environmental literacy and facilities, leading to inadequate waste management practices.

IV. *Waste Disposal Practices:* Unscientific disposal methods, including open dumping and burning, are prevalent in rural and transitional areas, posing environmental and health risks.

V. *Barriers to Effective SWM:* Challenges include limited awareness, inadequate infrastructure, and insufficient public participation, particularly in composting and recycling.

The study emphasizes the need for comprehensive, context-specific SWM strategies, community education, and the empowerment of women in waste management roles to improve environmental and public health outcomes especially in rural and transitional zones. This study also recommends raising awareness, changing attitude, improving knowledge and training and education particularly in rural areas. By encouraging segregation processes, implementing waste reduction strategies and promoting recycling and composting could be the better options for efficient waste management.

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