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Research Article

Quantification and Characterization of household solid waste at Urban Area of Kathmandu

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Abstract
Solid waste management can have significant positive and negative implications to the physical, social and economic environment and these implications are the function of management options adopted. The quantity and character of the waste generated changes with time and understanding these properties of waste in a locality form the basis of solid waste management. Thus, this research aims to understand the rate of solid waste generation in Kathmandu Metropolitan City, Ward 31, Shantinagar, and characterize the waste based on composition and management options. Waste generated by 100 households in 24 hours was collected, segregated, and weighed to quantify and characterize the waste generated at household level. Furthermore, an in-person interview was conducted with the household representatives using a semi-structured questionnaire to understand the options used for solid waste management at household level and their willingness to participate in waste segregation at source. The percentage composition of each waste category and per capita waste generated at household level was calculated. The relation of the per capita waste with number of family member was modeled by using linear regression. Data analysis was performed by using Microsoft Excel and R software. Significant fractions of the waste generated in the households were organic waste followed by paper waste which together makes up nearly 51% of total weight of the solid waste generated in the area. Per capita waste generation was found to be 402.7 grams per person per day. Per capita waste generation was a function of the number of family members with a decrease in per capita waste by an average of 111 g with an increase in one member in a family. Households who are involved in rooftop farming were segregating waste at the source indicating the local government can encourage rooftop farming to promote waste segregation at source.

Keywords: Characteristics, management, organic waste, per capita waste, waste segregation

Introduction
Municipal solid waste (MSW) encompasses all the unwanted and discarded materials generated during daily activities (Maharjan et al., 2019) in the municipal areas originating from a variety of sources including households, commercial areas and hospitals. Management of the solid waste in an environmentally friendly manner has been a global challenge particularly in the cities of the developing countries of Asia as these countries are undergoing swift urbanization and Solid waste management has emerged as an alarming issue (Khajuria et al., 2008). Ranges of options are available for the management of solid waste with their own strengths and limitations. The methods we choose should be acceptable as per the legal and social context besides being technically feasible, financially sustainable, and environmentally friendly (Abdel-Shafy & Mansour, 2018). Understanding the amount and types of waste generated under their jurisdiction enables the local government to choose from the range of available options for solid waste management and plan and execute the policies and planning accordingly (Kaza et al., 2018).

Solid waste management can have either positive or negative implications in physical, social and or economic aspects of the environment. As waste is primarily unused resources, with proper choice of management options we can generate economic and environmental benefits. In the meantime, municipal waste management represents the single particular item which cost significant fraction of municipal budget with the cities of lower middle-income countries being forced to spend about 20% of the total municipal budget in the sector alone with some spending in excess of half of their budget in SWM (Kaza et al., 2018). Solid waste dumping in the open ground has been a cause of emission to the nearby settlement in the areas where open dumping (Awasthi et al., 2021) or burning is practiced. Pollutants released due to open burning includes particulate matters ($PM_{2.5}$ and PM_{10}), black carbon, methane, sulphur dioxides (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), ammonia (NH_3) and non-methane volatile organic compounds (NMVOC) increasing the potentiality for different non-communicable diseases on the residents of the urban areas (Das et al., 2018).

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Despite the substantial growth in social, economic and environmental sector, solid waste management systems are inefficient particularly in the urban areas threatening the sustainability of the environmental systems (Maharjan et al., 2019). Since the enactment the enactment of the local self-governance act in 1999, solid waste management has been the responsibility of local government of Nepal (Thapa & KC, 2011). Analysis of the composition and quantity of different types of municipal waste is the foremost step for management of the waste (Karak et al., 2012) which is lacking. As the household waste contributes to 50 to 70% of the total municipal waste in Nepal (ADB, 2013) understanding their characteristics can guide management actions to a great extent. Furthermore, characterization of generated solid waste helps to determine the compostable and recyclable fraction of the waste in the region (Maskey & Singh, 2017). Organic fraction of the waste was found to be dominant fraction of the waste at Kathmandu and other cities of Nepal (ADB, 2013), however the composition and characteristics of the waste changes with the change in the economy of the region (Kaza et al., 2018) highlighting the need for periodic assessment waste generation rate and their characteristics.

In this study, we have attempted to explore the composition of solid waste produced and understand the factors that affect the waste generation in the region. Furthermore, the willingness of the local people to segregate the waste and motivating or hindering factors for segregation has been studied.

Materials and Methods

Study area

The Study was carried out in Kathmandu Metropolitan City ward number 31, Shantinagar (Latitude 26.748501, and Longitude 88.080307) has a population of 66,121 individuals (NSO, 2023). The area is located in the Midland region of the country with a subtropical climate dominated by monsoonal climate. The temperature of the area ranges from 0 to 35 degree Celsius and on average receives 1455 mm of precipitation each year. The ethnic composition of the area is mixed even though Kathmandu Valley is dominated by the Newar community.

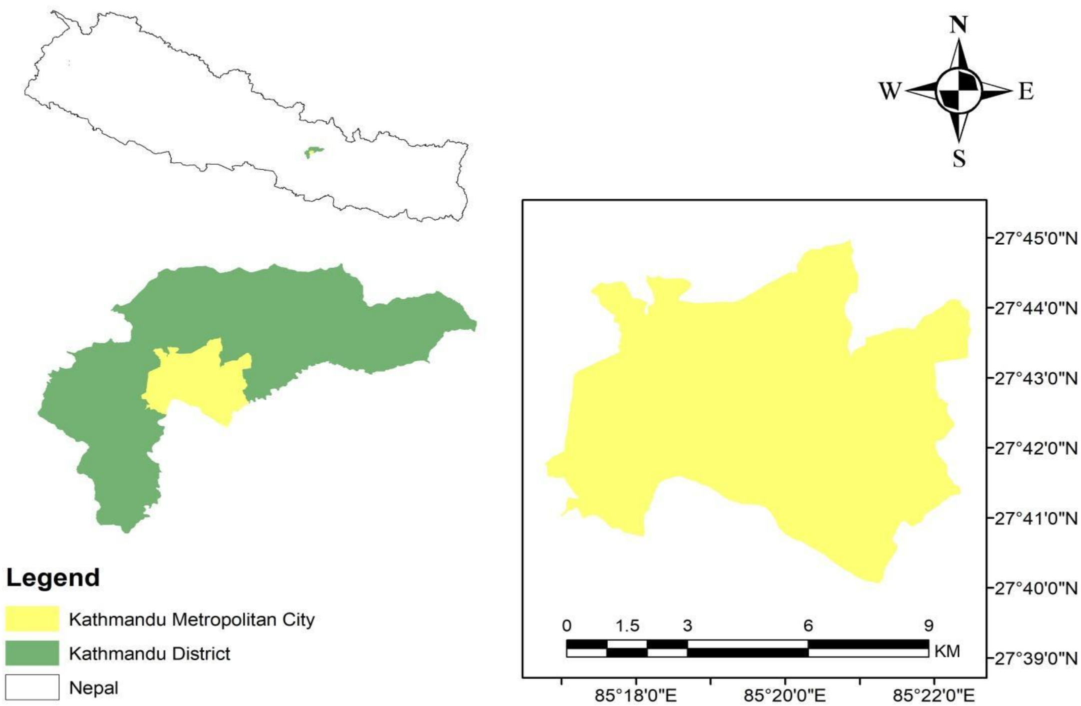

Figure 1 Map of study area showing Kathmandu Metropolitan City

Methods

Prior to the field visit, based on literature review, a checklist was prepared to note down the general information of the household and weight of organic, paper, plastics, glass, metal and other categories of waste. Furthermore, a standard questionnaire was prepared to collect information on general characteristics of the respondents, prevalent waste management practices and the willingness of the households to segregate and manage those wastes at household level.

The sample size for the study was calculated by using the commonly used methods in social survey (Arkin & Colton, 1963) as follows:

$$n = \frac{Z^2 \times p \times (1-p)}{d^2}$$

Where,
n = sample size
Z = confidence level (at 95% level Z = 1.96)
p = estimated population proportion
d = error limit of 10% (0.1)

We got the sample size of 96. Though, exact household number was not known, the estimated household was 400 in the study area. Thus, we used systematic methods to select the house for the survey. The sampling interval was found to be four. Thus, we surveyed in every fourth household.

During the field data collection, on the evening of the first day, by explaining the purpose of the data collection and taking their consent for participation on the research work a plastic bag large enough to hold the waste generated in 24 hours was handed over to them. They were asked to put all the waste generated in 24 hours. On the following day, plastic bags with the waste kept by the household were collected from the household and labeled properly. In-person interviews with the representatives were carried out to know the perception of the representatives of households using the standard questionnaire prepared. Questionnaire was administered using Nepali language and was entered in the sheet by translation. The collected sample of the waste was taken to the open space and was segregated into the predetermined category (Table 1) following the approach used to characterize waste at Gorkha (Maskey & Singh, 2017) with some modification. The fraction of the waste in each category was measured by using digital balance and noted on the respective checklist. Altogether, 100 households were surveyed in the period between October 31, 2021, and November 5, 2021.

Table 1 Examples of the different wastes and their respective categories used in the study

Category	Description
Organic	Kitchen waste (vegetable and fruit peelings and remains, eggshells, food leftovers/stale and tainted food, tea leaves, bones, oil, etc.), yard waste (leaves, grasses, weeds, plants, flowers, woods, branches, etc.
Paper	Notebooks, books, newspapers, cardboard.
Plastics	Polyethylene Terephthalate bottles such as beverage bottles; Low-Density Polyethylene such as trash bags and High-density polyethylene plastics such as bags and sacks, sheets, toiletries containers, condiment containers, water bottles, drums, toys; and Polystyrene such as food packages
Metals	aluminum cans, broken construction steel rods, broken umbrella metal rods, old utensils
Glass	beer bottles, alcohol bottles, jars, medicine bottles
Others	Rubbers, textiles, leathers, shoes, ceramics, medicines, light bulbs (Compact Fluorescent, Incandescent Bulbs), batteries, electronics (radios, wires), inert waste

Source: (Maskey & Singh, 2017)

After completion of the field work, the data were entered using Microsoft Excel 2010 and was analyzed using R and R-studio software (R Core Team, 2021; RStudio Team, 2022). Saphiro wilk test was done to test the normality of the data and as the data were not normal, Wilcoxon test was performed to assess significance of difference between the amount of various types of waste generated by small and medium sized households. In the study, the household was categorized into small and medium sized based on the number of the members in the family. The families with four or less were categorized as small sized families while the families with five to eight members were categorized as medium sized family. Linear Regression was performed to analyze the influence of the number of members in a family, address, occupation, and education of the respondents. Graphs were made using the ggplot2 package in R (Wickham, 2016).

Results and Discussion

General characteristics of respondents

Among the total respondents (N=100), 61% were female respondents and rest were male and the average age of the respondents was 34.7 years (Range 14 – 71, Standard deviation 11.767) with majority of the respondents completing the secondary level education (Table 2).

Table 2 Education level of the respondents (N= 100)

Education Level	Percentage
Illiterate	7%
Fundamental Education	6%
Secondary Level	54%
Undergraduate	23%
Graduate	10%

Among the respondents, more than one third of the respondents own their business (n= 36), rest were either housewives (n= 28) or involved in the service sector (n= 18) or were students (n= 18). The area was found to be predominated by families living in small size (n= 94) while the medium sized families were very few (n= 6). The average family size was 4.36 (range 2 to 8, sd=1.251).

Waste generation

A household at Shantinagar produced 1.599 kg of waste in 24-hour time with more than 28% of fraction contributed by the organic waste (Table 3).

Table 3 Summary statistics of the waste generated in 24 hours' time at household level

Waste Categories	Mean	Std. Deviation	Minimum	Maximum
Organic Waste (g)	437 (28.02%)	281 (14.23%)	125 (5.53%)	1571 (77.66%)
Plastic Waste (g)	315 (18.95%)	261 (15.69%)	0 (0%)	894 (69.8%)
Paper (g)	358 (22.67%)	288 (18.32%)	0 (0%)	980 (72.98%)
Metals (g)	179 (10.84%)	234 (13.67%)	0 (0%)	898 (61.06%)
Other (g)	314 (19.52%)	230 (13.51%)	0 (0%)	981 (57.11%)
Total Waste (g)	**1599**	**639**	**421**	**3644**

Solid waste generation and composition varies according to the country and is primarily determined by geographic position and economic status of that country (Das et al., 2019). In this study, organic waste was found to be the predominant waste category with around 28% of waste from organic origin. Organic waste has been reported as the predominant fraction of the waste in other studies conducted in the country. However, in our study only 28.02% of the waste was found to be organic waste, which is less than reported by other studies conducted in the country. For example, organic fraction of waste represented 51.57% of household waste in Hetauda Municipality (Neupane & Neupane, 2013) and 46% in Tulsipur of Dang District (Dangi et al., 2013). The fraction of the organic waste in the municipal waste developed based on the survey of the 271 municipalities of Nepal reports that 54.0% which includes paper waste, leather, and textiles also as organic waste (CBS, 2020). If we include paper waste into organic waste that would be near about 51% which makes our finding comparable. This indicates that in the urban areas of Nepal, both at the mid-hill region and Tarai region, slightly more than half of the wastes generated are of organic nature. Most of the urban areas of Nepal are in early phase of economic transformation from the agro based economics to service based. This might provide the plausible explanation of the lower fraction of organic waste than the national average, while being comparable among urban areas.

In this study, the fraction of plastic waste was nearly 19% and paper was nearly 23%. This value is higher than the value reported for Dang district, where 10% and 6% fraction of total were plastic and paper respectively (Dangi et al., 2013). Consumption of pre-manufactured or packaged food is expected to increase with an increase in per capita gross domestic product (per capita GDP) (Chen, 2018) and the transition of economy driven by increase in per capita GDP might be responsible for increased fraction of plastic and paper waste while decreased fraction of organic waste. There are previous reports of gradual increase in fraction of the plastic waste in Kathmandu valley (Pathak, 2019). The increased share of plastic waste in our study is in line with that finding and as the plastic waste might be a dominant fraction of waste in the region, management authority should focus on that aspect.

Biological and thermochemical conversion of plastics have been suggested as ecologically and economically better alternatives to the more conventional methods such as landfilling and burning (Idumah & Nwuzor, 2019). Plastic waste, which are essentially hydrocarbons with calorific values ranged between 30 and 40 MJ/kg, they can be used to generate electricity through burning or incineration (Abdel-Shafy & Mansour, 2018) and municipal solid waste of Kathmandu valley was reported to be sufficient to generate 19 MW of electricity (Sodari & Nakarmi, 2018).

Per capita waste generation

Each individual at Shantinagar area produced 402.67 grams of waste per day (Range 84.2 g to 1068.5, S.D= 202.2). Per capita waste generation differed significantly according to the family size with medium family size producing less waste per person per day than members of smaller families (W= 411, $p < 0.05$; Fig. 2).

Furthermore, per capita waste generation was significantly predicted by the family number. In a family, per capita waste generation is reduced on average by 101 grams upon the one unit increase in the family number (Table 4, Fig. 3).

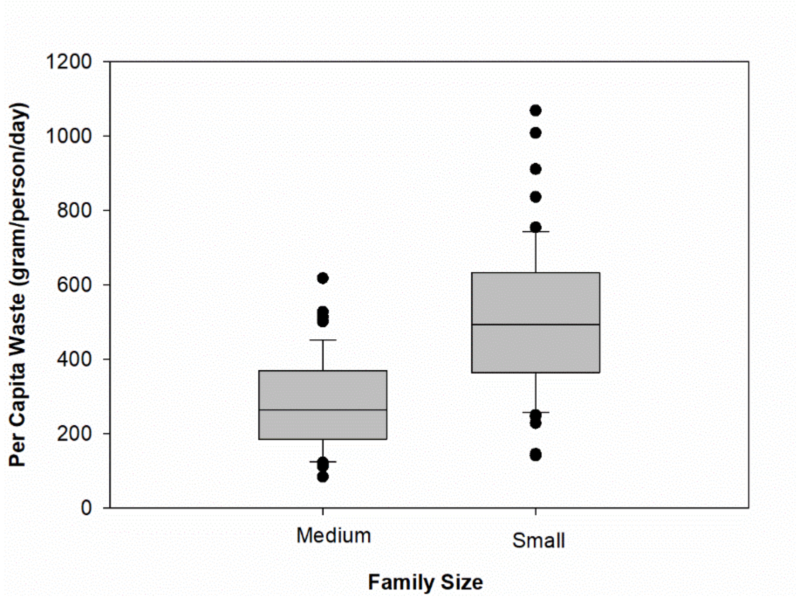

Figure 2 Variation in per capita waste generation according to family size

Table 4 Summary Statistics of Linear Regression of per capita waste generated with family number

Coefficients	Estimate	Standard Error	t value	Pr(>|t|)
Intercept	0.843	0.058	14.606	< 2e-16
Family number	**-0.101**	**0.013**	**-7.937**	**3.46E-12**

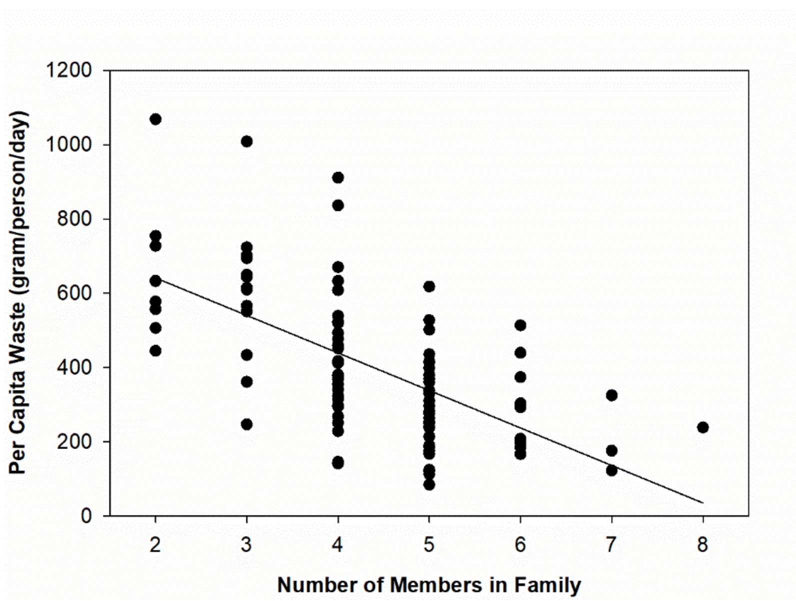

Figure 3 Relation of per capita waste generation with number of family member

The amount of the waste in the study area was found to be 402.67 gram per person per day which is higher than 330.4 g/capita/day at Tulsipur (Dangi et al., 2013) and 155.4 g/person/day at Hetauda (Neupane & Neupane, 2013). Growth in prosperity and movement to urban areas lead to an increase in per capita waste generation (Kaza et al., 2018). As the study was conducted at the core urban area, higher per capita waste generation was as expected. However, there are differences in scope of sampling and methodological issues that make comparison not fully compatible (Kaza et al., 2018). Furthermore, per capita waste generation was found to be significantly affected by the family number with decrease in waste generation with increase in family number. The amount of plastics and other packaging requirements does not change significantly with family size, thereby reducing the share of the waste when divided to each member. Our model explained just 39.13% of variation waste generation highlighting the need to consider other factors affecting per capita waste generation in the valley.

Waste management

All the respondents claimed to practice segregation by using separate containers for degradable and non-degradable containers. They were found to manage organic fraction of waste by composting. According to the respondents, solid waste in the region is managed by metropolitan authority and they collect waste once a week. For the collection, no separate time or vehicle is used for degradable and non-degradable waste indicating the lack of segregation by management authorities. This lack of segregation reduces the possibility of sustainable solid waste management.

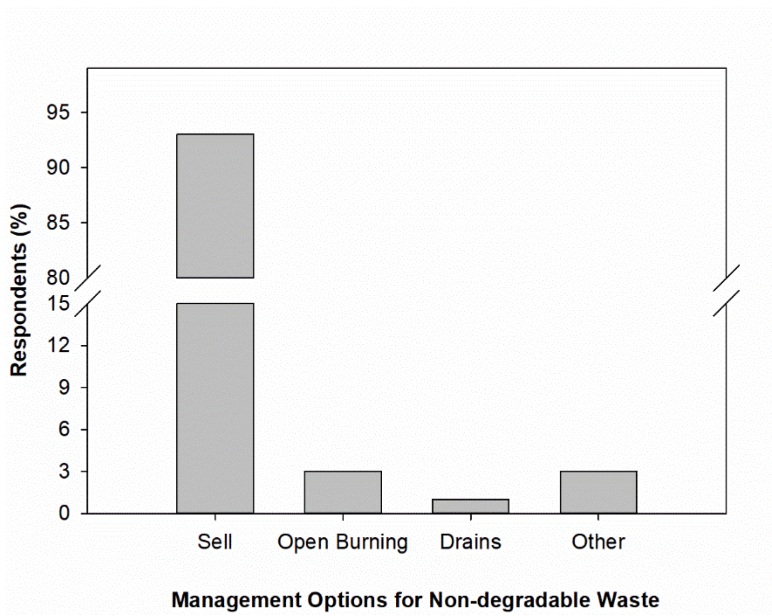

Figure 4 Management options used by local residents of Shantinagar for managing non-degradable waste

However, all the respondents reported to practice segregation and composting for organic fraction of waste which are encouraging signs. Composting has been the most economical method to manage organic solid waste in developing countries (Maskey & Singh, 2017). Furthermore, the non-degradable but recyclable wastes are sold to the informal waste pickers (Figure 4). The role of the informal waste workers in solid waste management in the cities of Nepal are highly acknowledged in the past as well (Dangi et al., 2017).

Conclusions

Solid waste, which has been the top prioritized issue for cities of developing countries, can be managed using the varieties of methods and techniques and the choice of appropriate management options are functions of characteristics and composition of the waste. Reduce, reuse and recycle (3R) is hailed as the basic principle for proper solid waste management and segregation of the waste is the basic step for implementing 3R principles. In lack of the state of art data on the composition and characteristics of the solid waste generated, Kathmandu valley is facing issues related to solid waste management inspiring us to undertake this study. Our study revealed that the amount of solid waste generated at Shantinagar area of Kathmandu valley is 402.67 g/person/day which is slightly higher than those reported from the studies done at Tulisipur and Hetauda. Whilst most of the organic waste in the area is managed through composting which has reduced waste volume that needs to be transported to the dumpsite. Among other factors, the study found that with an increase in family size the waste generation is less. This could be due to the fact that waste generated by many people at a time is less than that produced by a few people in a family, as the resource used by each family member is the same. Different social and economic factors govern the amount of waste generated at household level. Thus, we recommend the future studies to incorporate those factors in the design of the study. Furthermore, as roof top gardening inspired people to segregate waste, programs related to promotion of roof top gardening can benefit solid waste management in the city area.

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Author Contributions: MK: Conceptualization and overall study design (supporting), field work (lead), data management (lead), data analysis (supporting), draft preparation (lead) and finalization (supporting); BA: Conceptualization and overall study design (supporting), draft preparation (supporting), finalization (supporting), supervision (supporting); CMA: Conceptualization and overall study design (lead), data analysis (lead), draft preparation (supporting), finalization (lead), supervision (lead).

Conflicts of Interest: The author declares no conflicts of interest.

Data Availability Statement: The data that support the finding of this study are available from the corresponding author, upon reasonable request.

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