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ORIGINAL ARTICLE

Assessment of factors affecting household solid waste generation and its composition in Gulberg Town, Lahore, Pakistan

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Abstract This paper analyzes and compares the findings of the characterization study of collected solid waste from households of three different socioeconomic groups in Lahore, Pakistan, over the four seasons, i.e. Spring (March–April, 2008), Summer (May–June, 2008), Monsoon (August–September, 2008) and Winter (December 2008 and January 2009). The generation rate of waste was 0.96 kg/cap/day for high-income, 0.73 kg/cap/day for middle and 0.67 kg/cap/day for low-income group. The average of total household solid waste (HSW) generation is 0.79 kg/cap/day (including 0.75 kg/cap/day for spring, 0.77 kg/cap/day for summer, 0.86 kg/cap/day for monsoon and 0.76 kg/cap/day. The breakdown for the major physical components of the waste shows that organic waste accounts for the largest proportion (67.46 %). The relations between waste generation rates by physical category and subcategory, in addition to factors such as socioeconomic groups (population density levels, household income and household size), seasonal variation, and daily variation (difference of HSW generation among days of a week) were also analyzed. Statistical analysis shows that there was no significant difference in overall waste generation among days of a week. A significant difference between the seasons for food waste, cardboard, PET, HDPE, other hazardous waste, battery cells, and dust and stone ($p < 0.001$) was found. The generation rates were found to be higher when compared to other developing countries.

Keywords Household waste · Physical composition · Seasonal variations · Socioeconomic grouping · Correlation

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Introduction

The generation rate of municipal solid waste (MSW) has dramatically increased with the increase in population, economic growth and with the rise in living standards in developing countries. In most of the underdeveloped countries, the generated municipal solid waste is not managed properly and causes serious issues with respect to storage, collection and final disposal of waste [2, 4, 11, 12, 15, 20, 24]. Open dumping of waste on vacant plots and streets is the major problem [4, 15], along with improper storage systems for waste. Different types and sizes of garbage bins are placed at various locations without considering their suitability. Few of them were found fully filled save for those that were improperly placed. This is due to the lack of knowledge about quantity and composition of waste generated in the specific locations. The locations of communal storage bins were not evaluated scientifically. This problem leads to inappropriate collection routing and ultimately illegal open dumping of waste [5, 16, 20].

A reliable physical and chemical characterization of waste would surely be a necessity for a comprehensive and informative evaluation of management options [14, 16, 17, 27]. In fact, the demand for reliable information on waste quantity and detailed composition is difficult to achieve on a disaggregated level.

Compositional analyses of municipal waste have been carried out for many years by a number of researchers [1, 6–8, 13, 15, 20, 21, 25]. It was also observed that socio-economic structure and seasons influence the quantity and composition of MSW.

This study deals with the characteristics of MSW from Gulberg Town, which is one of the nine towns in Lahore, Pakistan, as a case of a developing country.

The main objective of the study was to develop a representative and statistically estimate the quantity and composition of the solid waste stream in Gulberg Town. The study investigated the quantity and quality of waste generated at the residential level and the determinants that can influence waste generation rates and composition, e.g. socioeconomic factors, seasons and weekly holidays. The data will be useful for decision-makers and waste managers,determining effective and efficient policies for the storage, collection and disposal of waste during weekdays and in different seasons, for different socioeconomic groups.

There are limited studies available on the quantity and composition of MSW. In Lahore, a solid waste management study was conducted by Indus Associated Consultants (PVT) Ltd. in 1983 as a part of the World Bank's Lahore Urban Development Project (LUDP; the project began in 1980).

The present study will be helpful in minimizing the risks to human health associated with solid waste management. The results from the present study cover all the three socioeconomic groups and can therefore be upscaled and applied to the entire city of Lahore with a population of 8 million.

Methodology

The research was carried out in the study area of Gulberg Town in Lahore City, Pakistan, in a population of 851,709. It comprises 15 administrative units, which are called union councils (Fig. 1).

Study area

Presently, the Solid Waste Management Department (SWMD) is responsible for the management of waste generated in the study area. The high-income group is being served by their society. The responsibility of SWMD is to collect the waste from houses, small heaps and containers and then transfer that waste to the dumping site. Handcarts and donkey carts are used for primary collection, i.e., from houses to storage bins while different collection vehicles are utilized for secondary collection, i.e., from storage container to dumping site. The amount of waste storage is about 60% of container capacity, and rate of collection is 50 %. In high-income group areas, the cost of solid waste management is covered through indirect taxation as well as sanitation charges of Rs. 150 ($1.6) per house. In middle-income and low-income group areas the cost of door to door collection is Rs. 50–100 ($0.8–1.2).

The high-income group considers SWM as an important and useful activity necessary for health and safety and is also willing to pay for it. However, in middle- and low-income groups the mentality tends to be that solid waste management is the responsibility of the SWMD, and that relevant taxes are a burden.

These feelings are the main reason that so many small open dumps exist in Lahore, in which there are no proper storage, collection and disposal systems, and consequently no scientific evaluation of waste generation rate and composition.

A 10-year disposal plan for the city of Lahore was prepared by the Lahore Municipal Corporation in December 1990. A feasibility study for a sanitary landfill with optimized gas extraction in Lahore was submitted by SWECO in 1992.

All the above mentioned studies discussed overall generation and composition, but did not address the factors of socioeconomic structure, seasons and days of the week.

Batool and Chaudhry [4] presented a study on the overall solid waste management system in Lahore and discussed the cost of the existing collection system,

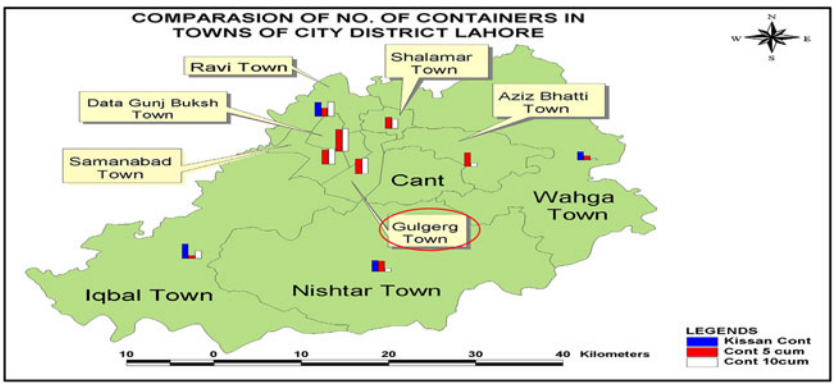

Fig. 1 Map of study area

proposing an improved collection system using the Life Cycle Inventory (LCI) modeling technique. The recycling potential in Lahore has been discussed by Batool [5].

Gulberg Town with a population of 851,709 comprises densely and relatively less densely populated areas. The town houses major and important commercial, administrative, and institutional buildings and areas of Lahore City (Fig. 1).

Sampling and measurement

Solid waste was collected directly from the houses where it was generated. This is an established method used in characterizing solid waste [16, 26]. The study was carried out at three socioeconomic levels and at four different times of the year. The socioeconomic levels studied were high-income [Rs. 60000 and above, ($700)], middle-income [Rs. 20000 ($ 250)] and low-income (Rs. 10000 ($115)). The socioeconomic level of the communities was based on the income of households and their property values [20]. In order to identify representative socioeconomic study areas for sampling and analysis of residential waste, a preliminary field study was conducted. The information collected on socioeconomic conditions was confirmed later after conducting interviews, which also gave information on the family size, education, profession and property status. During field surveys, some difficulties were met regarding data and sample collection, e.g. some respondents hesitated to give information about their income. It was therefore decided to use the size (area) of the houses and their property values to categorize the respective socioeconomic groups. In the low-income group, the respondents did not understand the purpose of the study and hesitated to cooperate in sample collection. They had to be convinced to participate in the sampling program so that improved solid waste management could be based on reliable data for waste generation and characterization.

To get representative results in the survey, we randomly selected 15 households from each socioeconomic category. The average size (number of persons) of the households in the high-, middle- and low-income groups were 6.9, 5.66 and 5.6, respectively. A total of 1,260 samples were collected over the whole period from three sampling areas.

$$15 \text{ households} \times 4 \text{ seasons} \times 3 \text{ socio economic groups} \times 7\text{days} = 1260$$

Sampling was conducted in March, April, May, June, August, September, December (2008) and January (2009), which included the spring, summer, monsoon and winter seasons. To develop a reliable and consistent information database, waste samples were collected for seven consecutive days per sampling period in each area.

Samples were collected with the help of employees of the City District Government of Lahore (CDGL). The selected households were informed and collection bags (capacity 10–15 kg) were provided for one week in each season.

Household waste has been classified into nineteen main fractions, based on physical composition. The composition used is based on research data from 2003 on Danish household waste presented by Riber [23]. At the end of the sorting process, the fractions were weighed separately on a calibrated digital scale. A questionnaire survey was also conducted in each sampling area in every season.

Results and discussion

Composition and generation of waste in Gulberg Town, Lahore

A total of 1,260 samples were collected, 420 from each income group. Waste generation rate and physical composition in four seasons (spring, summer, monsoon, and winter) is presented in Table 1. The average HSW generation in Gulberg Town was 0.79 kg/cap/day (including 0.75 kg/cap/day for spring, 0.77 kg/cap/day for summer, 0.86 kg/cap/day for monsoon and 0.76 kg/cap/day for winter season. The overall generation rate for Gulberg Town was calculated at 0.79 kg/cap/day. This represents the total amount of waste that was deposited in or around the bins for collection. It does not include the source-separated material at the household level.

It was found that present waste generation rates are higher when compared to other developing countries, like Mexico (specifically, Guadalajara and Morelia) [8, 10], Bangladesh [25], Haiti [28], and Bostswana (specifically, Gabarone) [29], but almost the same when compared to a study conducted by Ojeda-Benitez [20] and Abu Dhabi, UAE [30].

The data are expected to be useful for decision-makers, researchers, manufacturers, consumers, and recycling companies.

Regarding the physical categories presented in Table 2, it is apparent that food waste accounted for the largest part of the total (61.46 %) followed by dust and stone (8.39 %), yard waste (6.45 %) and textiles (4.19 %).

Quantity of food waste shows a similar trend of organic waste generation in developing countries [28].

Relevant factors influencing waste generation

The generation rate and composition of HSW depends on many factors that must be taken into consideration when trying to explain waste generation, both general and site-specific.

Table 1 Generation rate of waste generated by households of the three socioeconomic groups during the four seasons (kg/cap/day)

Items	Low [Rs. 10000 ($115)]					Middle [Rs. 20000 ($ 250)]					High [Rs. 60000 and above, ($700)]				
	Spring	Summer	Monsoon	Winter	Avg.	Spring	Summer	Monsoon	Winter	Avg.	Spring	Summer	Monsoon	Winter	Avg.
Food waste	0.405	0.454	0.604	0.436	0.475	0.367	0.495	0.627	0.398	0.472	0.381	0.515	0.580	0.429	0.477
Yard waste	0.001	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.001	0.166	0.173	0.199	0.201	0.185
Wood	0.001	0.001	0.002	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.004	0.003	0.004	0.006	0.004
Paper	0.010	0.010	0.013	0.011	0.011	0.025	0.024	0.027	0.029	0.026	0.043	0.021	0.018	0.042	0.031
Cardboard	0.012	0.006	0.005	0.006	0.007	0.014	0.008	0.009	0.014	0.011	0.031	0.006	0.008	0.009	0.013
Diapers	0.006	0.005	0.007	0.007	0.006	0.012	0.014	0.014	0.014	0.014	0.026	0.011	0.018	0.026	0.020
Pet	0.002	0.002	0.003	0.001	0.002	0.003	0.004	0.005	0.002	0.003	0.003	0.001	0.002	0.001	0.002
HDPE	0.010	0.005	0.003	0.015	0.008	0.014	0.009	0.007	0.021	0.013	0.024	0.008	0.016	0.023	0.018
Others plastic	0.013	0.006	0.002	0.006	0.007	0.016	0.004	0.013	0.019	0.013	0.031	0.016	0.026	0.029	0.025
Packing material	0.005	0.005	0.006	0.006	0.006	0.014	0.015	0.016	0.017	0.016	0.052	0.035	0.031	0.058	0.044
Polythene bags	0.015	0.020	0.009	0.018	0.015	0.021	0.020	0.015	0.022	0.020	0.022	0.022	0.019	0.022	0.021
Rubber	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.004	0.002	0.005	0.003	0.003
Leather	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.001
Dust and stone	0.086	0.078	0.046	0.078	0.072	0.072	0.073	0.077	0.079	0.075	0.049	0.058	0.021	0.034	0.041
Metal	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.000	0.000	0.001	0.015	0.007	0.005	0.011	0.010
Glass	0.036	0.013	0.005	0.023	0.020	0.045	0.017	0.018	0.026	0.026	0.069	0.063	0.043	0.048	0.056
Textile	0.056	0.042	0.031	0.055	0.046	0.043	0.029	0.029	0.039	0.035	0.015	0.011	0.006	0.008	0.010
Hazardous	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.002	0.001	0.001	0.002	0.001	0.001	0.001	0.001
Battery/ cell	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Sharps/ infect	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Others	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Total	0.660	0.650	0.737	0.664	0.678	0.661	0.712	0.859	0.683	0.729	0.939	0.952	1.003	0.952	0.962

Researchers in this subject area, [3, 10, 13, 16, 21] reported that some socioeconomic characteristics of households affect the overall waste generation rates and their composition. In addition, other researchers found that seasonal variation influences waste generation rate and waste characteristics [9, 14, 16, 22]. Meanwhile, Qu [21] reported that waste generation and its composition were affected by daily variation. In this study, the authors also analyzed relations between waste generation rates by physical category and subcategory, in addition to factors such as socioeconomic (population density levels, household income and household size), seasonal variation (dry season and rainy season), and daily variation (difference of HSW generation among days of a week).

Effect of specific weekdays on waste generation

We observed that the quantity of waste generated varies during the weekdays, with the highest quantities generated and collected on Monday (day 1 of sampling). This trend was found in each income group. During the questionnaire surveys, the reason behind this fact was revealed to be due to activities of Sunday, which is considered a holiday that most people spend at home. The weekly clean-up day is also Sunday for most of the population, thus most of the waste is generated on Sundays. The difference between the waste generated on Monday and other weekdays was greatest in the high-income group; according to household interviews, this was due to the fact that parties were mostly arranged on Saturday nights and Sundays in this group. The low-income group and a large proportion of the middle-income group reported not being able to afford to throw parties.

Our study also found that food waste is dumped more on Mondays than on other days of the week, largely because Sundays are used to prepare food to last a number of days. For example, spinach dishes are prepared on Sundays, and since only the leaves are separated for cooking, the remainder of the plant is thrown away, contributing to increased waste on Mondays.

The data we gathered on the quantity of waste collected each day shows these differences, as presented in Fig. 2.

Table 2 Percentage and composition of waste collected in Gulberg Town

Items	Amount of waste collected (%)
Food waste	61.46
Yard waste	6.45
Wood	0.22
Paper	2.8
Cardboard	1.33
Diapers	1.62
Pet	0.34
HDPE	1.6
Other plastics	1.81
Packing material	2.51
Polythene bags	2.41
Rubber	0.16
Leather	0.02
Dust and stone	8.39
Metal	0.4
Glass	4.1
Textile	4.19
Hazardous	0.12
Battery cell	0.02
Sharps/infect	0.02
Others	0.03
Total	100

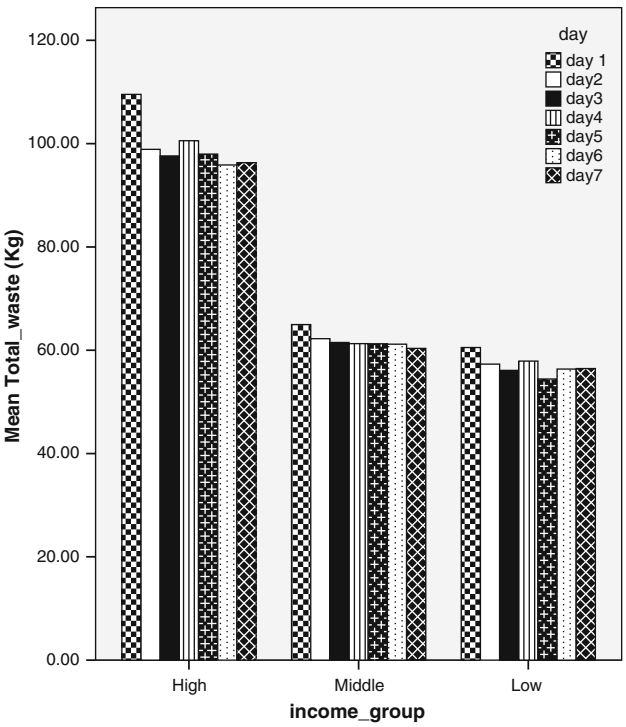

Fig. 2 Daily variations in waste generation in Gulberg Town for each income group

However, ANOVA statistical analyses showed that these differences among days of the week were not overall significant (Table 3).

Effect of seasons on generation of waste

An ANOVA statistical analysis revealed a significant difference between the seasons for food waste, cardboard, PET, HDPE, other hazardous waste, battery cells, and dust and stone ($p < 0.001$) (Table 4). Other components showed no significant differences. Figures 3 and 4 show that more waste is produced during the monsoon and summer months compared to the winter and spring.

In our comparison of seasonal data, it was found that more food waste was generated in monsoon and summer seasons than in spring and winter seasons. Fruits and vegetables are used more frequently in these months because of food preferences related to the hot and humid weather. Skins, seeds, and stalks of fruit and vegetables are typically discarded as waste. In these seasons, people like to eat more vegetables than meat so the peels of vegetables contribute to increases in the quantity of waste. Mangoes, melons and water melons are also consumed more frequently, producing substantial quantities of peels and seeds. During monsoon season, the dust is reduced due to wet weather, while HDPE, cardboard and hazardous waste are stored to be disposed later on.

Effect of economic status on generation of waste

Figure 5 shows the differences in composition of waste within the socioeconomic groups. The generation analysis revealed that certain categories of household waste showed a positive and strong correlation to generation and income. Table 5 shows *p* value and r value for different items in the household waste stream per income level. It was observed that as income raises so does the amount of food waste, cardboard, polythene and hazardous waste; the correlation is strong (*p* value < 0.000). However, it was found that two components of the household waste stream, packaging material and yard waste, are strongly correlated with income group ($r = 0.923$ and 0.965, respectively). The reason for the strong correlation between the high-income group and yard waste is the fact that 90 % of high-income households have houses with areas between 2 kanal (9,000 sq ft) to 4 kanal (18,000 sq ft) and enough space for gardens and lawns. The high-income group also produces more packing materials since they buy well-packaged luxury goods and often consume packaged food. On the other hand, middle- and low-income houses have areas of 3–5 merlas (675 to 1,125 sq ft). They have limited space

Table 3 ANOVA results for the impact of specific weekdays on waste generation

	df	*F*	Sig.
Food	6	0.170	0.984
Yard Waste	6	0.008	1.000
Wood	6	0.014	1.000
Paper	6	0.191	0.979
Cardboard	6	0.047	1.000
Diapers	6	0.337	0.915
Pet	6	0.250	0.958
HDPE	6	0.100	0.996
Other plastic	6	0.095	0.997
Packing material	6	0.041	1.000
Polythene	6	1.430	0.214
Rubber	6	0.040	1.000
Leather	6	0.015	1.000
Dust and stone	6	0.529	0.785
Metal	6	0.137	0.991
Glass	6	0.065	0.999
Textile	6	0.294	0.938
Hazardous	6	0.068	0.999
Battery cell	6	0.021	1.000
Sharps/infect	6	0.200	0.976
Other hazardous	6	0.056	0.999

Table 4 ANOVA results for the effects of seasons on the generation of waste

Items	*df*	*F*	Sig.
Food	3	59.952	0.000
Yard waste	3	0.083	0.969
Wood	3	0.280	0.840
Paper	3	3.470	0.020
Cardboard	3	21.463	0.000
Diapers	3	2.239	0.090
Pet	3	8.552	0.000
HDPE	3	18.480	0.000
Other plastic	3	4.823	0.004
Packing material	3	1.208	0.312
Polythene	3	2.477	0.067
Rubber	3	1.681	0.178
Leather	3	3.183	0.028
Dust and stone	3	9.626	0.000
Metal	3	3.902	0.012
Glass	3	6.005	0.001
Textile	3	4.368	0.007
Hazardous	3	4.984	0.003
Battery cell	3	6.564	0.001
Sharps/infect	3	4.823	0.004
Other hazardous	3	34.834	0.000

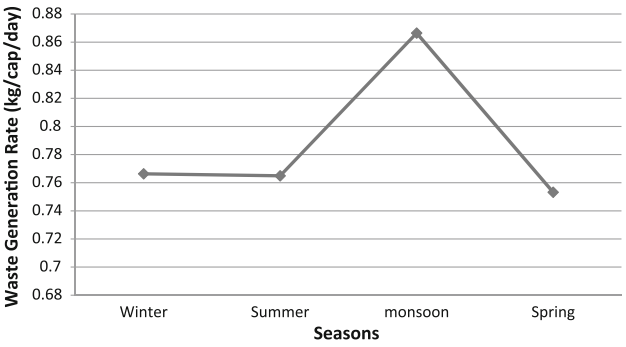

Fig. 3 Seasonal variations in the waste generation in Gulberg Town for each income group

for living. Yard waste is therefore produced mainly by the high-income group.

Dust and stone (pieces of construction material, which may include rock, pieces of bricks, mortar and plaster) are generated mainly by low- and middle-income groups. This category shows a negative correlation with increasing income. The low- and middle-income groups produce more dust and stone because they live in dilapidated areas, with little vegetation (Lahore lies in a dry subtropical area), high traffic density and crumbling roads.

Diapers are expensive and thus are used more by the high-income group. Household waste from the high-income group tends to contain less PET bottles because these are given away to house servants and maids who are often very poor and usually sell or reuse the bottles. The reuse of PET bottles is not as common in middle-income households; instead, these items are often thrown out in the garbage. Textile waste generation is inversely related to income. This is because the high-income group buys ready-made or tailored cloths and, when they are no longer wanted, gives them to poor people, so there is little textile waste in municipal garbage. People in the low- and middle-income group often buy cloth, and women in this group cut and sew the clothes, producing textile waste. Because of financial hardship, low- and middle-income residents repair their clothes and continue to use them until they cannot be used anymore, thus discarding the textiles in collected waste.

The low- and middle-income groups buy cheap hazardous material like pesticides/insecticides, disinfectants, solvents acids and alkalies. The solvent acids and alkalies are easily available in Pakistan, used as drain openers and bathroom cleaners. The oil of motorcycles, rickshaws and cars are also typically changed at home in these income groups, and all the leftovers, or degraded and expired items are thrown into the trash. The high-income group is typically well-educated and aware of the dangers of these items. They never change oil at home and often hire the services of professionals for cleaning, disinfecting and

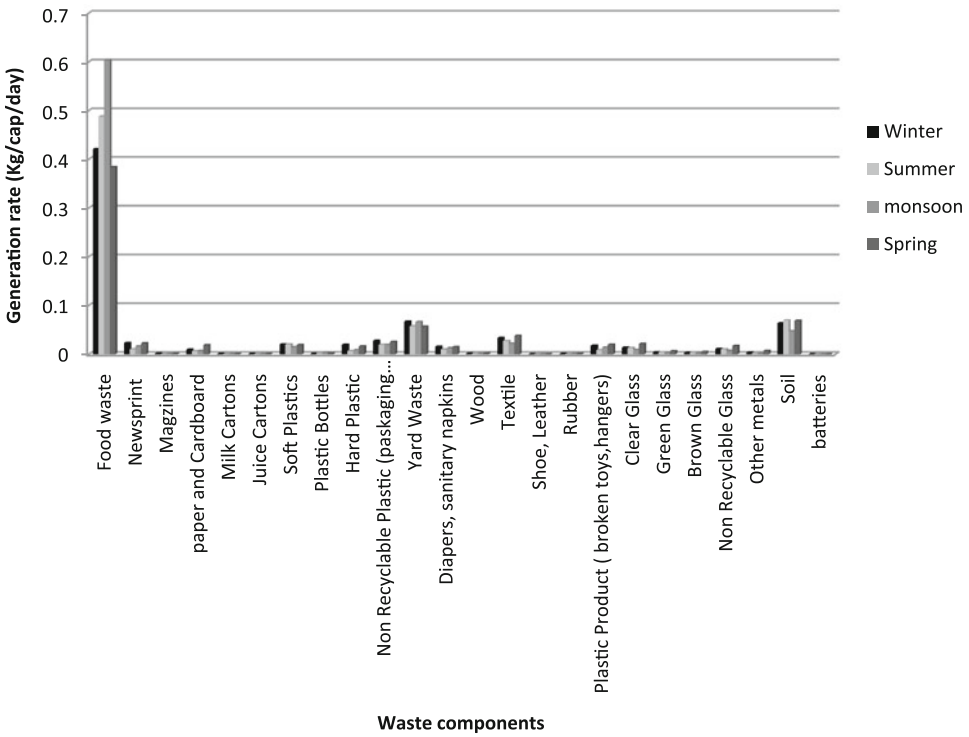

Fig. 4 Quantity and composition of waste generated in different seasons

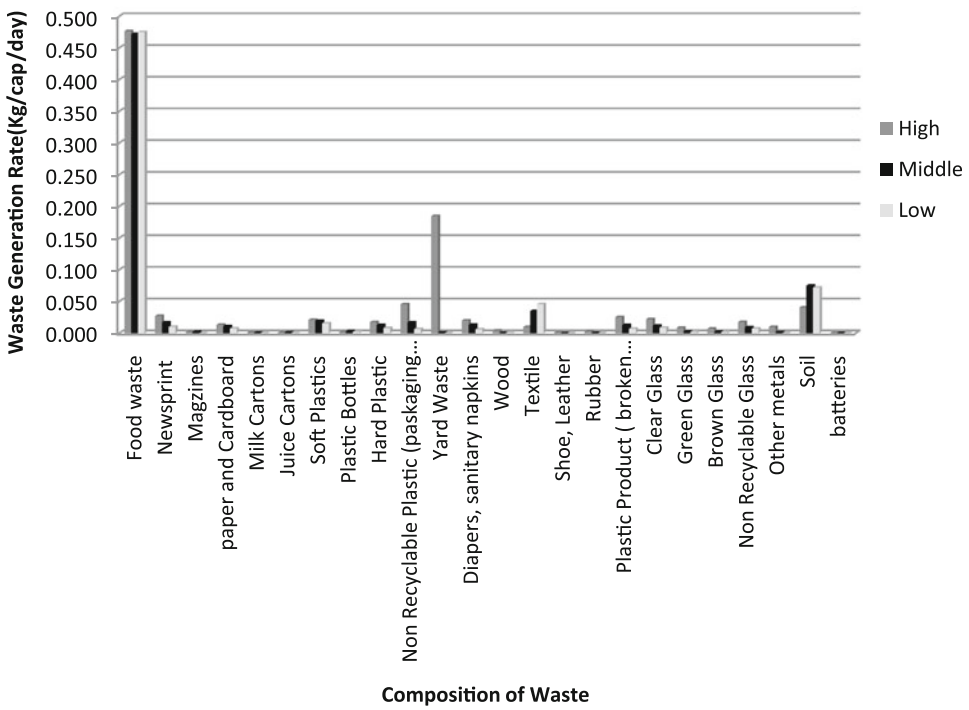

Fig. 5 Variations in waste generation within socioeconomic groups in Gulberg Town

eliminating insects or pests; thus, this group contributes less hazardous waste materials to overall municipal waste.

In our study, municipal solid waste was sorted into 19 fractions, with the highest fraction being organic kitchen waste (average 61.46 %). We found that this organic fraction of MSW is also high in other Asian countries like China, Bangladesh, Maldives, India and Nepal. It tends to represent about 34–70 % of MSW totals, which is higher than the organic waste percentage of European countries, i.e., 20–50 %. The food waste content is lower, however, than the ash and dust content in the MSW of India [19]. In this study, the second major fraction of collected MSW was dust and stone, at 8.39 %. The amount of recyclables, e.g.,

Table 5 Correlation values between income groups and waste items collected in Gulberg Town

Items	Correlation coefficient (r)	p value
Food	−0.474	0.00
Yard waste	0.965	0.00
Wood	0.873	0.00
Paper	0.701	0.00
Cardboard	0.41	0.00
Diapers	0.78	0.00
Pet	−0.143	0.196
HDPE	0.616	0.00
Other plastic	0.854	0.00
Packing material	0.923	0.00
Polythene	0.479	0.00
Rubber	0.887	0.00
Leather	0.799	0.00
Dust and stone	−0.544	0.00
Metal	0.821	0.00
Glass	0.853	0.00
Textile	−0.829	0.00
Hazardous	0.496	0.00
Battery cell	0.688	0.00
Sharps/infect	0.426	0.00
Other hazardous	−0.036	0.746

paper, plastic, glass, and metal in collected waste, depends on the scavenging activity. We observed that these items are typically reused, recycled, or sold to the junkshops for recycling. Their amount in the main waste stream is much lower than the organic fraction. The same situation was found through a literature review of an Indian study. The amount of paper and plastic, especially packaging material, is also higher in some Asian countries where the tourism industry is expanding. Finally, climatic conditions influence the composition of MSW, e.g., the ash content of MSW in China is very high due to the use of coal as an energy source in areas of low temperature [18]. In this study, higher levels of dust and stone, and zero content of ash were found in Lahore's collected household waste.

Conclusion

The present study is the first step in the development of a proper waste management system. Knowledge of the variation in quantity and composition of waste in different seasons and in different income groups orovides a good and solid basis for decision-makers at each and every step in this field, i.e., in the citing of locations for storage bins, the design of collection routes, or in suggesting new landfill sites.

MSW generated in Gulberg Town of Lahore, Pakistan within three income levels was characterized at four different times of the year (spring, 2008, Summer, 2008, Monsoon, 2008 and Winter 2008–2009). A total of 6,155.516 kg of MSW were analyzed, from 1,260 samples generated in 45 households during the four seasons mentioned above. The average amount of waste per capita generated was 0.78 kg/cap/day, for all three socioeconomic levels taken together. The results show a trend that correlates higher income to a higher generation of solid waste. Regarding the seasonal influence on waste generation, we observed an increase in waste during monsoon months and a decrease in spring and winter. The same pattern was observed in each income group.

Other final suggestions regarding improvement of the existing municipal solid waste management system include:

- Private sector participation
- Involvement of community
- Involvement of NGOs

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