Evaluation of factors affecting Residential solid waste composition and its generation in Iqbal Town, Faisalabad, Pakistan

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Abstract

Southeast Asian Nations (ASEANs) are facing various problems among which waste is the most evident environmental problem. GHG emissions from waste sector are predicted to rise in near future especially in developing countries. Although in Pakistan's national GHG inventory, emissions from waste sector compared to other sectors are little but there are problems in accounting and reporting of emissions from this sector. The waste sector occupies an exclusive position as a potential reducer of greenhouse gas (GHG) emissions. The current study aims to quantify and compare the solid waste that was being collected from residential sector of Iqbal Town Faisalabad, Pakistan on the basis of their categorization in three socioeconomic groups for all the four seasons i.e. i.e. Winter (December 2015 and January 2016), Spring (March–April, 2016), Summer (June-July 2016), Monsoon (September-October, 2016) that contributed towards global warming trends along with essential information, that is required for MSWM.

The findings of this study will ultimately aid the next study of quantification of GHG emission from waste sector of Faisalabad. The indices used in the study were attained from FWMC and health center of Faisalabad. The entire town was divided into three socio-economic classes (Lower, Middle and Upper class) according to their income. Labeled garbage collection bags were distributed 24 hour prior to the collection to the selected house (15 houses of each class) of the study for all the seven days of a week in each season. Collected waste was segregated into eleven categories' (Food, Plastic, Wood, Dust & Stone, Diapers, Paper, Metal, Glass, Cloth, pet, lather, rubber, Hazardous and others. A comparison was plotted against each class for all the categories and results revealed the waste generation trends as Upper Class> Middle Class≥ Low Class. The segregated waste trends were shown as Food>Dust>Cloth≥Plastic>Paper>Wood>Metal≥Glass>Pet≥rubber>Lather. According to the results, the recorded waste generation rate was 0.84 kg/capita/day for upper class, 0.65 kg/capita/day for lower class and 0.62 kg/capita/day for middle class. It was estimated that in 133 UCs of Faisalabad, 1750 ton of waste generated on daily basis, out of which 950-1000 tons per day were collected and transported to dumping sites by FWMC. Similarly, 0.53 kg/capita waste generation rate was recorded according to the FWMC indices. The results of study also revealed that a population of 3.053 million occupied by Faisalabad city generated 1702 tons of waste daily only from residential sector. The waste segregation results showed that largest portion of the waste is accounted for organic waste (72.67 %). It was concluded that waste generation rate of Pakistan was higher than other developing countries.

Key words: FWMC, UC, Green-house gas Emissions, Waste Sector, Faisalabad City.

Introduction

Among various global environmental issues, solid waste becomes a matter of serious concern (Sharholy et al., 2007; Seng et al., 2010; Delgado et al., 2015; Fu et al., 2015; Wang and Geng, 2015; Khan et al., 2016). Modern society's inefficiency symbolized with waste as well as nominated as society with misallocated resources. In contrast, demand for new products increased with passing of time that enforce to deplete massive amount of natural resources and ultimately huge amount of solid waste generation (Menikpura et al., 2013; Plaganyi et al., 2013). Southeast Asian Nations (ASEANs) are facing various problems among which waste is the most evident environmental problem. The quantity of MSW has been increased several times in urban centers of developing countries during last few decades. Urbanization, industrialization, economic development, changing income, consumption pattern changes and increasing population resulted in enlarged solid waste generation (Guerrero et al., 2013; Warunasinghe and Yapa, 2016) and also a diversification of the generated solid waste types in developing countries (Gu and Fujiwara, 2009; Minghua et al., 2009; Ngoc and Schnitzer, 2009; Weng and Fujiwara, 2011; Guerrero, 2013; Gu et al., 2015; Wang and Geng, 2015). The household waste (HW) is an important part of the municipal solid waste (MSW) stream. HW waste also indicates the socio-economical conditions of the households and urban society. There is an interesting relationship between buying capacity of the urban population (Suthar & Singh, 2015). There are many social and environmental factors that may influence the rate of generated waste in different socioeconomic groups (Khan et al., 2016). Many of the environmental problems created with an increased generation in waste, because numerous cities does not capable to handle wastes due to technical, financial, institutional, knowledge, regulatory as well as public participation short comings (Ngoc and Schnitzer, 2009). The consequence is environmental degradation and hazardeous to inhabitants, caused by insufficient and improper waste disposal (Ngoc and Schnitzer, 2009; Khan et al., 2016; Warunasinghe and Yapa, 2016).

Cities are facing serious problem regarding waste is inadequate waste storage system along with open waste dumping on streets and vacant plots (Sharholy, et al., 2006; Gomez et al., 2008; Batool and Chaudhry, 2009; Warunasinghe and Yapa, 2016). Rapid economic growth, increasing population and rising changes in living values will hasten the future municipal solid waste generation rate (Guerrero et al., 2013; Warunasinghe and Yapa, 2016). The location for communal storage bins were not scientifically evaluated that may leads towards adverse impact on all components of the human health and environment (Kansal, 2002; Jha et al., 2003; Rathi, 2006; Sharholy et al., 2005; Ray et al., 2005; Sharholy, et., 2007; Khan et al., 2016; Warunasinghe and Yapa, 2016). This problem ultimately leads to unsuitable routes of collection and illegal open waste dumping (Ojeda-Benitez, 2003; Batool et al., 2008; Gomez et al, 2009). Apart from the release of GHG into atmosphere, these open dumped MSW sites are causing global warming / climate changes with no energy recovery.

A consistent waste characterization (physical and chemical) would certainly be a requirement for an informative and comprehensive assessment of management plans (US EPA, 2002; Gidarakos, 2006; Gomez et al., 2009)

The current study deals with the municipal solid waste characteristics collected from Iqbal Town, one among the four towns of Faisalabad, Pakistan. The study was designed with objective to develop a representative approximation of the composition and quantity of the solid waste generated in Iqbal Town, Faisalabad. The study also evaluated the quality and quantity of waste

produced at the domestic stage along with determinants that can manipulate composition and generation rate of domestic solid waste, e.g. seasons, weekdays and socioeconomic factors. There is no study existed on the composition and quantity of MSW in Faisalabad.

Methodology

The current study was planned to quantify the domestic waste generation from the city of Faisalabad, Pakistan (latitude 31°4187′N, longitude 73°0791′E, 184·4m asl) (Ahmad & Schmitz 2011; Cheema et al., 2006; Farooqi 2005; Hussain & Lee 2009; Iqbal et al., 2011; Rio *et al*. 2012;), which is the third largest city of Pakistan.

Currently, Faisalabad Waste Management Company (FWMC) is accountable for the management of waste produced in the investigated area. The FWMC is responsible for the collection of waste from houses, society bins and small heaps and then shift the collected waste to the disposal site.

Donkey carts and handcarts are mainly used for prime collection, i.e., from households to storage space bins while secondary collection (from storage sites to disposal site) would be carried out by different collection vehicles.

According to Faisalabad Waste Management Company (FWMC), the city of Faisalabad is divided into four Towns named as (Iqbal Town, Jinaah Town, Lyallpur Town and Madina Town) and subdivided into 113 union councils. The estimated population of Faisalabad for the year of 2016 is 3,675,000 (FWMC, 2016); it was preferred purposely for the research. This study was conducted for the four seasons; (December 2015 and January 2016), Spring (March–April, 2016), summer (June-July 2016), Monsoon (September-October, 2016) to identify the qualitative and quantitative aspects of domestic solid waste generation.

The rate of solid waste generation was probable to fluctuate in different socioeconomic groups due to many social and environmental factors. To cover this issue, the scenario of solid waste generation and socioeconomic status of the study area was identified by conducting a survey with an aim to observe the physical composition of the investigated area and to gather information regarding quality and quantity of solid waste. A questionnaire was designed to collect data on household level on daily social waste and socioeconomic traits. Data were also assembled through both interviews and direct observations with household members, by the officials of Faisalabad Waste Management Company (FWMC), that were responsible for the collection, transportation along with disposal of municipal solid waste in the targeted area. After survey reports compilation, the whole area of study was divided into three different socioeconomic groups based on the monthly income of household: high income group ((Rs. 100,000 and above ($ 953), middle income group (Rs. 35,000 ($ 333) and low income group (Rs. 10,000 9 ($ 95)). Solid waste was directly collected from the representative houses. This is a conventional method to be used in characterization of solid waste (Gomez et al., 2009; Jadoon et al., 2014).

To obtain representative results, fifteen households from each socioeconomic class were selected randomly (Sujauddin et al., 2008)

3 socio economic groups × 15 households × 7days × 4 seasons = 1260

For a consistent and reliable database development, samples of waste were assembled for seven successive days during sampling period in study area.

During the questionnaire survey, sampling bags (similar size and with particular coding of the respondent) were distributed to the selected areas 24 hours before sample collection for seven days of a week for the four seasons (cool winter, spring season, hot summer, and autumn).
Samples were characterized after collection. After physical characterization, recyclables were segregated according to their categories and weighed and recorded. The same practice was conducted for consecutive seven days of the study week in each season for targeted 45 households. During segregation, waste is segregated into sixteen categories depends on their physical composition. The used physical segregation is derived from Danish household waste research data, 2003 documented by Riber *et al.*, 2009.

Results and Discussion

Current household waste disposal practices

The Iqbal Town is divided into several subzones/colonies as per FWMC record. A total of 28 union councils/colonies were selected to study the household waste generation rate and its characterization. The collection, transportation and management of MSW of the city are mainly governed by the Faisalabad waste management company (FWMC). The facilities and services at secondary MSW collection points have been provided by the FWMC in these areas. The collected HW is then further transported to the local MSW disposal site of the city. In these areas, domestic solid waste is collected through tractor-trailer system, Donkey cars, hand cart etc arranged by FWMC. The number of community containers in each block/colony is fixed on the basis of the population and number of houses in the block/colony. In few areas of the blocks the people have to dispose their HW on roadsides, open spaces, waste-land, etc. just to avoid necessary walk to dump garbage in the fixed community containers, located slightly far from the residential locations. The fractions of HW like discarded food or vegetable wastes are sometime removed by the scavengers (street dogs, cows, birds, etc.) from the community containers. Rag pickers also picks recyclable (polythene bags, plastic scrap, polythene bottles, metals, paper, glass, etc.) waste articles/items from the community containers which has been appeared as major problem for municipality people in proper waste collection process. There is no formal HW segregation, resource recovery and composting facility is available in the city. The project to establish a landfill site in the study region is only in paper since last 5 years.

Household waste generation rate and composition in Iqbal Town

The generation rate of domestic solid waste and its composition for the selected sites for four seasons is presented in Table 1. As per calculation, a contribution of 420 samples from each of the socioeconomic class resulted in the form of 1,260 samples after consecutive seven days of study weeks. The average generation rate of domestic solid waste was estimated 0.70 kg/capita/day (counting 0.71 kg/capita/day for winter, 0.69 kg/capita/day for spring, 0.75 kg/capita/day for summer and 0.68 kg/capita/day for Monsoon season. This estimation covers the total waste that was dumped in/around the collection bins as well as collected from house hold levels. It was investigated that current rate of waste generation are higher when plotted a comparison with other developing nations, like Mexico (specially, Morelia and Guadalajara) (Bernache-Perez et al., 2001; Buenrostro et al., 2001), Bangladesh (Sujauddin et al., 2008), Haiti (Feniel Philippie and Marc Culot, 2009), and Bostswana (specifically, Gabarone) (Bolaane and Ali, 2004), while same trends were observed when compared the results with a study carried out by Ojeda-Benitez, 2003 and UAE, Abu Dhabi (Abu Qdais, 1997).

Table1: Domestic waste generation rate of the categorized socioeconomic groups during the four seasons (kg/cap/day)

Items	High [Rs. 10,000 (US $95)					Middle [Rs. 35,000 (US $333)]					Low [Rs. ≥1,00,000 (US $953)]				
	Winter	Spring	Summer	Monsoon	Average	Winter	Spring	Summer	Monsoon	Average	Winter	Spring	Summer	Monsoon	Average
Food Waste	0.547	0.510	0.616	0.540	0.553	0.513	0.497	0.539	0.506	0.514	0.498	0.493	0.487	0.417	0.474
Yard Waste	0.171	0.165	0.125	0.137	0.150	0.000	0.002	0.001	0.001	0.001	0.000	0.000	0.001	0.000	0.000
Dust & Stone	0.023	0.029	0.033	0.036	0.030	0.048	0.045	0.059	0.060	0.051	0.059	0.076	0.078	0.086	0.075
Diapers	0.017	0.012	0.010	0.013	0.013	0.042	0.008	0.009	0.011	0.010	0.004	0.002	0.002	0.006	0.004
Paper	0.023	0.021	0.024	0.029	0.025	0.005	0.007	0.007	0.005	0.006	0.001	0.001	0.005	0.006	0.003
Wood	0.009	0.013	0.039	0.012	0.018	0.003	0.002	0.005	0.009	0.005	0.002	0.003	0.004	0.008	0.004
Plastic	0.015	0.015	0.022	0.022	0.019	0.006	0.009	0.006	0.005	0.006	0.002	0.002	0.005	0.001	0.002
Pet	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.005	0.002	0.005	0.004
Polythene Bags	0.021	0.022	0.019	0.022	0.021	0.020	0.016	0.020	0.020	0.019	0.013	0.016	0.014	0.017	0.015
Textile	0.005	0.007	0.005	0.004	0.005	0.043	0.026	0.038	0.020	0.032	0.062	0.040	0.047	0.030	0.045
Metal	0.006	0.007	0.008	0.007	0.007	0.000	0.000	0.003	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Glass	0.004	0.005	0.002	0.002	0.003	0.001	0.000	0.001	0.001	0.001	0.000	0.000	0.000	0.001	0.000
Rubber	0.001	0.001	0.001	0.002	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
Leather	0.001	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	0.000
Hazardous	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000

Others	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
Total	0.843	0.810	0.906	0.828	0.847	0.647	0.614	0.687	0.639	0.646	0.645	0.640	0.646	0.577	0.627

The %age physical fraction of collected waste from study sites is described in Table 2, it is visible that the largest portion of the total waste comprised with food waste (72.67 %) followed by dust (7.37 %), yard waste (7.11 %) and textiles (3.87 %). The findings of our study are quite resembled with studies carried out in other developing countries (Feniel Philippie, Marc Culot, 2009).

In terms of the quantity, the food wastes have been appeared as the major faction of the HW than others. The quantity of all the major items in HW (viz. paper, plastic and polythene bags, diapers, woody items, glass/ceramics, rubber, leather, pet and miscellaneous items) recorded during the survey varied significantly among different locations of the city. It is to be mentioned here that hazardous waste contents in HW was comparatively lower as compared to cities/towns of the developed countries.

Table 2: Waste composition and %age in Iqbal Town

Items	%age amount of waste collected
Food Waste	**72.67**
Yard Waste	**7.11**
Dust & Stone	**7.37**
Diapers	**1.24**
Paper	**1.59**
Wood	**1.27**
Plastic	**1.31**
Pet	**0.26**
Polythene Bags	**2.59**
Textile	**3.87**
Metal	**0.38**
Glass	**0.21**
Rubber	**0.06**

Leather	**0.02**
Hazardous	**0.05**
Others	**0**

The majority of hazardous component (as included in miscellaneous waste fraction of HW) in HW consists of dry cell, batteries, computer CD, empty containers of household insecticides and pesticides, etc. The segregation of recyclable items and reselling of electronic and electrical equipments, as whole or in parts, at household level is the major cause of low volume of hazardous items in HW in the city. The block-wise difference in HW composition could be mainly due to the economic structure, social rank and housing location in the city. It was also observed during the waste sampling operation that the local residents isolate reusable/recyclable items from the HW and sells directly to interim waste buyers (Pheriwala) or to local small vendors. The food/kitchen waste in HW, as recordedin this study, is comparable with several other cities of developing world: 69.3% – Beijing, China (Qu et al., 2009), 62.0% –Chittagong, Bangladesh (Sujauddin et al., 2008), 71% – Kathmandu,Nepal (Dangi et al., 2011), 77–78% – Mekong Delta, Vietnam (Thanh et al., 2010), 76.3% Damaturu, Nigeria (Babalola, Ishaku, Basu, &Majid, 2010). Results clearly suggest that food/kitchen waste was the major component of HW in the city (Jadoon et al., 2014). In developing countries the majority of the rural as well as urban population cooks their daily meals in house kitchens and usually therefore the food waste (wastes from kitchen) is the major component of the HWs.

Factors affecting rate of waste generation

It is needed to consider range of factors including socio-economic status, cultural conditions, food habits, season and geographical locations that directly affected the composition of household waste generation (Buenrostro et al., 2001; Gidarakos et al., 2006; Bandara et al., 2007; Boldrin and Christensen, 2009; Gomez et al., 2009; Qu et al., 2009)

In current study, relations of waste generation with its physical category as well as subcategory, besides other factors like daily difference (variation of solid waste production within week days), socioeconomic (household size and income, levels of population density) and seasonal variation (Warm, cold, rainy and dry season).

Seasonal influence on waste generation

It was clear from Figures 1 and 2 that that extra waste was generated in the summer and winter seasons in comparison of the spring and monsoon season in which a larger fraction comprised with food waste. More vegetables and fruits are used during winter and summer seasons because consumption rate for food increased in hot and cold weather, so the vegetables and fruits peels contribute to increases the waste quantity. Seeds, skins and stalks of vegetables and fruit are usually discarded as waste. Water melons, mangoes and melons are also consumed more frequently in summer, generating significant quantities of seeds and peels. In winter, spinach and other green vegetables are highly consumed along with dry fruits and fresh fruits which contribute in an increased rate of waste in these seasons.

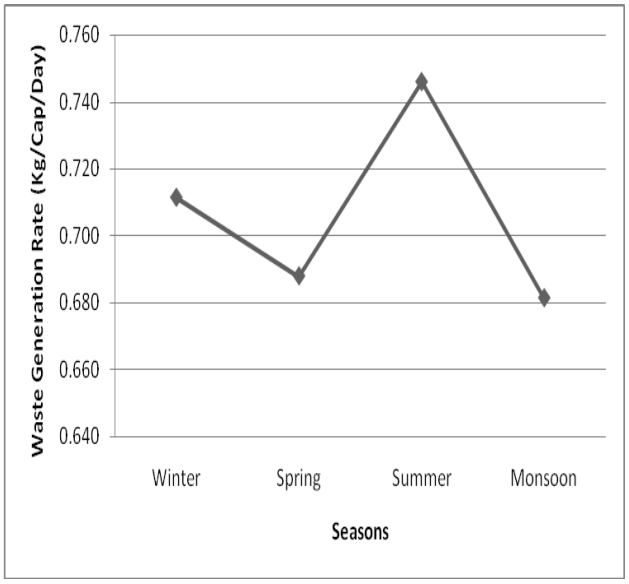

Fig 1: Seasonal waste generation trends

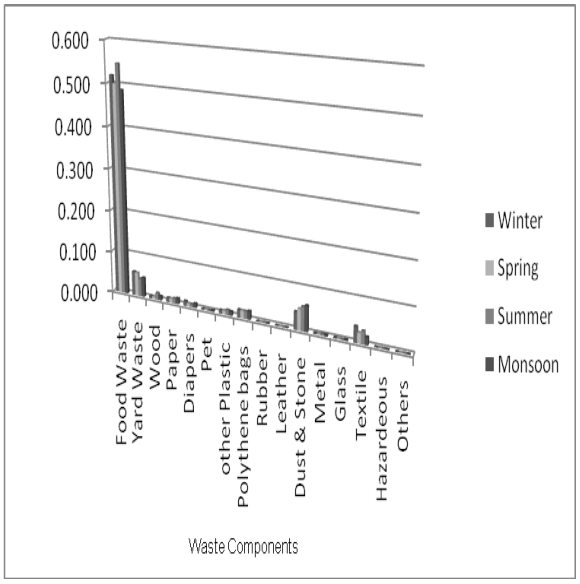

Fig 2: Waste generation rate with seasonal changes

Socioeconomic status and waste generation:

Figures 3 and 4 present the differences in waste composition contained by the socioeconomic groups. Results of the study revealed a direct relation between amounts of waste generated with level of income as income increases so does the quantity of organic waste, yard waste and polythene bags. However, it was found that yard waste is strongly associated with income level. The fact behind this correlation is that 85 % of high class people have houses that covers the areas between 1 kanal (4500 sq ft) to 2 kanal (9,000 sq ft) with sufficient space for lawns and gardens.

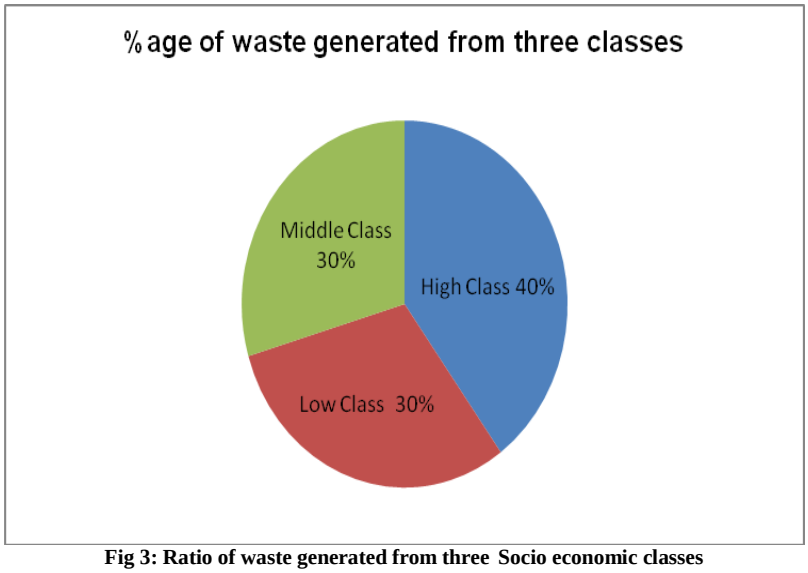

Fig 3: Ratio of waste generated from three Socio economic classes

In contrast, low and middle class houses comprise areas of 3–5 merlas (675 to 1,125 sq ft). They are confined with restricted space for living. That's why yard waste is associated mostly with the upper class.

Dust is produced mainly by lower and middle class. The middle and low class groups generate extra dust because they reside in houses constructed with mud in dilapidated areas near crumbling roads and high traffic density with little vegetation.
Diapers are mostly used in high income class because these are expensive. Less pet bottles are sorted from the waste of high class households as those people gave such sort of stuff to their poor maids and servants to reuse or sell these bottles.

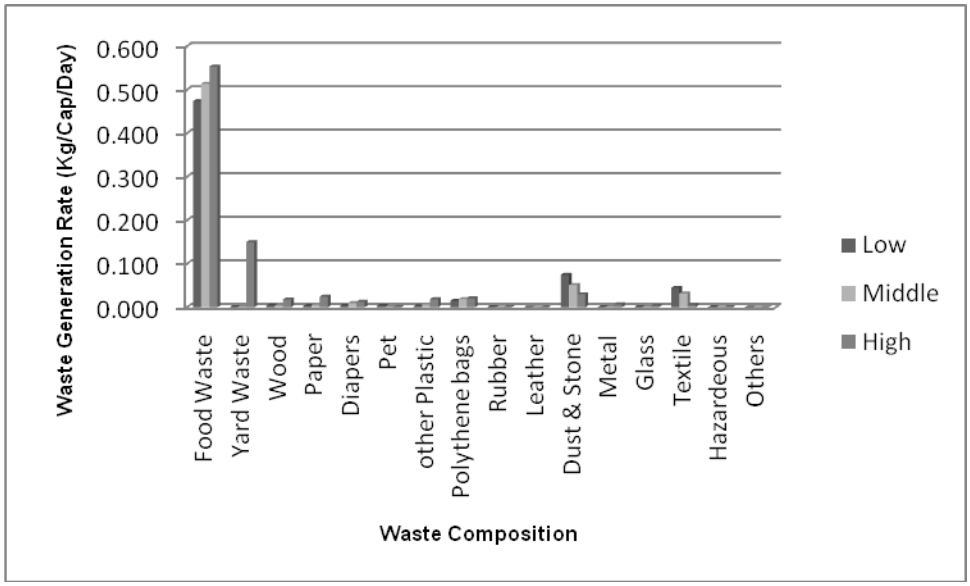

Fig 4: Waste composition in three socioeconomic classes

An inverse relation found between textile waste generation and income level. This reason is the high class group used tailored or readymade cloths and gives them to the needy people when they are no longer wanted, so there is slender textile waste in upper class municipal waste. While, inhabitants in the middle and low income class often purchase fabric, and women of this class sew the clothes for their own as well as for women of high class to earn money, thus producing more textile waste. People of middle and low class fix their clothes to be used until they tore into pieces, thus discarding them into waste, just because of financial hardship.
Hazardous material of low quality like disinfectants, alkalies, insecticides, pesticides and solvent acids are easily available in the market and accessible to the middle and low income class because of cheap rates. In Pakistan, the alkalies and solvent acids are used as bathroom cleaners and drain openers. The people of this class provide tuning services to their rickshaws, motorbikes and other automobiles at home, and expired, degraded or all the leftovers items are discarded into the trash. The trend is far more change in high class as those people are highly educated and well aware about the threats posed by these items and always hire professional to get services for disinfecting and cleaning activities thus adding minute contribution towards overall solid waste.
In current research, domestic solid waste was segregated into 16 fragments, in which kitchen organic waste accounting the highest fraction (average 72.67 %). We studied that in other countries of Asia like Bangladesh, Maldives, China, India, and Nepal, this organic fragment of municipal solid waste is also at extreme. This fraction of organic waste in Asian countries signify about 34–70 % of total domestic solid waste, which is above than the percentage of kitchen organic waste in European regions, i.e., 20–50 %. However, dust and ash contents are higher

than the food waste in municipal solid waste of India (NRI, India, 2003). In our study, the second highest portion of sampled MSW was dirt/dust, at 7.37 %. Although, the amount of recyclables, e.g., plastic, paper, metal and glass in collected waste sample, depends on the activity of scavengers. The quantity of recyclables is much lower in main stream of waste than organic fraction because such items are usually recycled, sold to the scrap yards for recycling purposes or reused. In the literature review of the studies conducted in India and Bangladesh, the same circumstances were found. Finally, composition of municipal solid waste also influenced by the climatic conditions of the area, e.g., in MSW of low temperature areas of China, the contents of ash are very high because of the coal use as a source of energy (NRI, China, 2003). In current study, dust level was higher as Faisalabad is categorized as dust hole because of its geography while zero ash content were estimated in Faisalabad's collected domestic waste.

Conclusion

The current study is the initiative for proper waste management practices development in Faisalabad. Detailed discussion about relation between waste composition and its generation rate with different socioeconomic groups and seasonal variations provide a solid ground for policy makers at each step in this field. Population of Iqbal Town, Faisalabad, Pakistan was divided into three socioeconomic levels according to their income level and waste generated from these groups was characterized at four seasons of the year (Winter 2015-2016, spring, 2016, Summer, 2016 and Monsoon, 2016). A total of 1,544.028 kg of municipal solid waste was analyzed, from representative 1,260 samples collected from 45 households throughout the above mentioned seasons. The per capita waste generation rate was recorded 0.70 kg/capita/day, for all three socioeconomic classes in combine. Results also revealed the fact that high income class producing more solid waste. Seasonal variations strongly influence the waste generation rate in all socioeconomic classes in almost same pattern. It is suggested finally to ensure the participation of private sector, NGOs and community involvement to improve the existing municipal solid waste management system include:

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