Seasonal characterization of municipal solid waste in the city of Jammu, India

Pervez Alam¹, Mohd. Aamir Mazhar², Afzal Husain Khan³, Nadeem A Khan²*, Alaa El Din Mahmoud⁴

¹Department of Civil Engineering, BGSB University J & K, India
²Department of Chemistry, Jamia Millia Islamia, New Delhi, India
³Civil Engineering Department, Jazan University, 114 Jazan, Saudi Arabia.
⁴Environmental Sciences Department, Faculty of Science, Alexandria University, 21511, Alexandria, Egypt.

* Corresponding author: nadeem.khan@mecw.ac.in

Abstract. Increasing municipal solid waste (MSW) of different forms on account of rise in population has demonstrated the need of studying the seasonal characterization of municipal solid waste in residential area of Jammu city, India. This work analyses the characteristics of MSW for three diverse periods of a year (winter, spring and summer) collected directly from the families at three diverse economic levels of selected residential area. Weighing machine was used to weight the waste material separated in tarpaulin sheet. For all the three socio-economic levels, the average measure of waste produced was 2.96 kg/capita/day. The lowest income groups generated about 2.36 to 2.71 kg/capita/day of waste while the highest income groups generated about 2.4 to 3.7 kg/capita/day of waste. We found that summer season has the highest of waste generation whereas winter has the lowest. The characterization values of the weighed municipal solid waste shows organic fraction of 82.73% followed by the plastic waste with 6.78% and then the combination of paper and cardboard with 6.78%. Other wastes viz metals, glass etc. were found to be 2.51 % in total.

Keywords: Municipal Solid Waste, Jammu, Income, Characterization, residents, household, economic level, Population

1. Introduction
The exponential population growth and change in life style have increased the demand of various products which have led to increase in solid waste of different forms [1]. The Municipal solid waste (MSW) consists of household, business squanders, development/destruction trash, sanitation waste and the waste gathered by a municipal authority. Solid wastes comprise all waste materials except released gases and liquid wastes. The sources of MSW are numerous including residential, industrial, agricultural, medical, commercial, and institutional. Some of them can burn and others can be recycled but most of them can neither be burnt nor be recycled. The amount of recyclable material in MSW is however amazingly low as these are segregated by the rag pickers at the point of generation or assortment points or at the point of disposal. These recyclable wastes are disposed generally from...
residential areas, apartments, hospitals, schools, factories etc. Out of these it has been found that about 55% -65% of total MSW is generated from the households and about 35% to 45% of total MSW is generated from educational institutes and business areas like offices, hospitals etc. (EPA, Municipal Solid Waste Generation, Recycling, Disposal, 2006).

When these wastes are dumped in an unscientific manner; non-engineered landfill or on spaces open to atmosphere, not only the quality of air is affected, soil as well as groundwater gets contaminated due to percolation of leachate of landfill into the groundwater. This causes serious health problems to humans besides effecting the environment [2]. Hence, integrated management of MSW is more important in cities of country like India, whose urban population has increased five times in last six decades.

In India, the management of solid waste is not getting the required attention and has become major environmental issue about loads of waste dissipated in practically all urban areas [3]. The services provided by the municipal authorities are outdated with no infrastructure or financial back-up [4]. In 2007, there was a study done in Jalandhar; city of India by Kothiyal et. al., [5]. They found that it was a troublesome circumstance for the urban municipal agencies to manage the MSW because of prevalence of unplanned dumping, non-availability of data with respect to production and characterization of waste generated.

It is worth mentioning that increasing the quantity of solid wastes with each passing day is making it more and more difficult to find a concrete solution that will lead to lesser impact of MSW on the environment. For a city, making a sustainable arrangement by method of generating energy from waste treatment is a significant problematic job on account of various rationales as topography of the area, climatic conditions, socio-economic angles etc., the composition and quantity of the wastes. The arrangement, attributes, and amount of MSW from a municipality is an element of a few restrictions like food habit, climatic conditions, standard of living, business exercises, tourism, etc. [6]. For various seasons, the characterization of MSW can give us a thought regarding the game plans to be made for assortment, transportation and removal of various amount of MSW produced [7-8].

In this article, the overall composition of the MSW produced, the variety in composition and attributes concerning the individual areas, various income groups in different territories and different weather conditions has been studied. As far as generation of MSW of Jammu was concerned, the residential areas of three different socio-economic groups were selected for the study for three different periods of the year. LEVEL I- High income/wages group (Highest socio-economic group), LEVEL II- Medium wages/income group (Medium socio-economic group) and, LEVEL III- Low income/wages group (Lowest socio-economic group).The periods of the study were varying from late winter to spring and summer (showing a gradual change of temperature) and hence come up with a scientific solution and way of disposing of solid waste according to its type, composition and determine the dominant type of solid waste in different socio-economic levels and in different seasons. By characterizing the solid wastes seasonally and socio-economically, we can easily determine the major solid waste components at different seasons of a year and from different classes. This will easily act as a preliminary data for the implementation of a waste management plan for Jammu. This study holds more importance as no study like this has been carried out in past especially in this part of the world.

2. Study Area

The northern-most state of India is Jammu and Kashmir, the state consists of three regions: Jammu, the Kashmir valley and Ladakh. Jammu is situated at 32.73°N latitude and 74.87°E longitude, having an altitude of 327m above mean sea level. It is lying at uneven crests of low elevations at the Shivalik hills. The city is lying along the river Tawi dividing the old region on the right bank and the new development on the left bank of the river. Jammu features a humid subtropical climate having highest temperature of around 47 °C in summers and having lowest temperature below 4 °C in the winters. During monsoon season (June to September) the major rainfall occurs in the region of about 669 mm and have an average annual rainfall of 1100 mm. As per 2011 census, the population of Jammu was
1,529,958 constituting 813,821 males and 716,137 females. The occupation pattern of the area as per census 2011 is 134576 number of cultivators, 27523 number of Agriculture Labourer, 8042 number of Businessman and 358190 others. Out of total workforce the agricultural labourer constitutes about 25%.

Figure 1. Map of Jammu City (Source: Google Maps and Jammu Municipal Corporation).

2.1 Description of MSW collection system and disposal in Jammu
In Jammu city around 350-400 metric tons of waste is generated per day from various generation points like domestic, commercial centres, hospitals, educational institutions, slaughterhouses, eateries, markets, industries, etc. The waste is gathered from these spots by trucks and is unloaded transparently at two non-engineered and inappropriate landfill sites one at Bhagwati Nagar close to the river Tawi and other at Bandurakh in an informal way. The height of these dumping sites has reached about 8 to 12 m. The rag pickers also collect some of the waste from these sites and sell it in the vicinity. The MSW from various parts of the city is being dumped at these two sites without having appropriate solid waste management system.

3. Materials and Methods
3.1 Collection of Solid waste
The polythene bin bags (refuse bags) were purchased from the local market in a bulk amount. The bags were then labelled with codes referring to which economic level and the status of the household selected. By labelling the bags, the practice of sorting the waste samples of different economic levels and households became quite easy and simple. The codes used were:
- EL-I-XX- representing Economic Level- I
- EL-II-XX- representing Level-II
- EL-III-XX- representing Level-III
Where XX denotes Number of households e.g. EL-I-01- refers to the 1st house of Economic Level-I
3.2 Tarpaulin Sheet
A tarpaulin sheet was used to scatter the MSW sample for the separation process. This made the separation procedure easy, quick, and more effective.

3.3 Digital Weighing Machine:
A digital weighing machine of 10 kg capacity was used to weigh the collected samples of MSW. The final weight of sample was calculated after the separation process for each household and each economic level, this process was used to calculate the fraction of the type of waste present in the sample of that day. Moreover, it was used to calculate the per capita per day amount of MSW generated. Different fractions of the samples were weighed, and the readings were used for further analyses of MSW.

3.4 Method of Collection
The collection of MSW was done precisely from the point of generation i.e. households. It is the most common method of characterization for solid waste [9].

3.5 Population classification based on socio-economic levels
The classification of populace according to socio-economic conditions was aided by the Department of Sociology of Jammu University and JK ENVIS survey of Jammu city.

3.6 Selection of neighborhood for sample collection
After classifying the population according to socio-economic condition, the neighbourhood for the collection of waste was selected by the results of the previous survey and by the local knowledge of the residents and personal experience of being resident of the area. The neighbourhoods selected for the purpose of collection of MSW samples were:
• Gandhi Nagar- Economic Level-I (With highest level of Income)
• New Plot, Sarwal- Economic Level-II (People with medium wages)
• Muthi- Economic Level-III (Lowest level income)

3.7 Determination, collection, classification, quantification and analysis of samples.
The total number of samples collected for each economic level and all the seasons were 315. They were collected by visiting each house and collecting them by hand in bin bags which were labelled with the codes of economic levels by taking proper precautions and safety measures like gloves, masks etc. The MSW samples so collected were brought home and separated on a tarpaulin sheet. The total weight of the samples for each household of an economic level was calculated. The samples were separated into different waste composition fractions. Finally, analysis of result was carried out which is discussed in the following section.

4. Results and discussion
Jammu city has a total population of 1,529,958 [10]. This population is split up into two groups i.e. the Economically Active population and the Economically Inactive Population. About 41% of the total population is economically active (including main workers and marginal workers) and 59% population is economically inactive.

Most of the economically active population is scattered through the neighbourhood of Gandhi Nagar, Channi Himmat, Sainik Colony and Trikuta Nagar. The reason behind all these developed settlements is the location of all the city’s major offices including governmental offices and private shopping complexes are located there. The classification of the socio-economic levels was done by selecting the area with the most developed estates and then assigning it as Economic level. The composition and the amount of MSW generated varies at different places and for different seasons because of its diversity [11-12]. Because of the heterogeneity and inconstancy of MSW, an arithmetical tool is needed to gauge the quantity of tests to be examined. From a factual perspective,
the precision in deciding these boundaries will increment as the quantity of tests to be examined increments. Simultaneously, the quantity of tests ought to be reasonable, considering the assets accessible. Five samples for each economic level were collected. The total numbers of samples collected were 35 for each economic level in a season i.e., summer, winter and spring making it a total of 105 for all three economic levels. Overall, 315 samples were collected. The samples were separated into different waste composition fractions like organic wastes, paper & cardboard waste, plastic wastes, metal wastes, glass wastes, others etc. The different waste fractions are shown below in table 1.

Table 1. Different waste components found in MSW in Jammu city of India.

| Waste Fractions | Waste Components                                      | Percentage of each fraction |
|-----------------|-------------------------------------------------------|----------------------------|
| Organic         | Food, animal excreta, wood, leaves, garden trimmings. | 48.43                      |
| Paper & Cardboard| Bills, Office paper, milk boxes, fruit boxes, egg containers. | 20.06                      |
| Plastic         | Polythene bags, Food Containers, Small Plastic.       | 8.43                       |
| Metal           | Ferrous and Non-Ferrous material.                     | 2.39                       |
| Glass           | Beer, Wine and food bottles.                          | 1.49                       |
| Inert           | Construction waste, Dust etc.                         | 17.8                       |
| Other           | Small toys, Clothes, fabric, textiles, hair, etc.     | 1.40                       |

The number of residents of each household in each economic level was counted and the total weight of samples for all the samplings were calculated and noted down in a tabular form. Each economic level showing the amount of MSW generated by each household in each economic level and for all three seasons is shown in Table 2. Total solid generated in per capita per day in Jammu city is also been discussed in table 2.
Table 2. MSW generated by each household in each economic levels: (a) ECONOMIC LEVEL-I, (b) ECONOMIC LEVEL-II (c) ECONOMIC LEVEL-III and for all three seasons in Jammu city of India.

| No. of households | Winter  | Spring  | Summer  |
|-------------------|---------|---------|---------|
|                   | No. of Residents | MSW (kg) | No. of residents | MSW (kg) | No. of Residents | MSW (kg) |
| 1                 | 6       | 15.430  | 6       | 21.312  | 6       | 22.634  |
| 2                 | 6       | 16.804  | 6       | 19.978  | 6       | 21.844  |
| 3                 | 5       | 11.616  | 5       | 17.112  | 5       | 20.988  |
| 4                 | 5       | 10.876  | 5       | 17.264  | 5       | 19.464  |
| 5                 | 6       | 16.358  | 6       | 19.274  | 6       | 18.926  |
| 6                 | 4       | 9.440   | 4       | 16.258  | 4       | 15.390  |
| 7                 | 4       | 9.554   | 4       | 14.744  | 4       | 17.112  |
| 8                 | 5       | 10.836  | 5       | 15.569  | 5       | 17.325  |
| 9                 | 5       | 12.816  | 5       | 16.756  | 5       | 18.654  |
| 10                | 4       | 9.110   | 4       | 15.645  | 4       | 16.658  |
| 11                | 8       | 17.366  | 8       | 18.364  | 8       | 21.367  |
| 12                | 6       | 16.321  | 6       | 18.226  | 6       | 19.328  |
| 13                | 4       | 10.126  | 4       | 16.256  | 4       | 16.440  |
| 14                | 5       | 9.624   | 5       | 16.739  | 5       | 20.789  |
| 15                | 5       | 11.369  | 5       | 17.970  | 5       | 21.791  |
| Total             | 78      | 187.646 | 78      | 261.467 | 78      | 288.710 |
| Total no. of samples | 85     | 85      | 85      |
## (b) ECONOMIC LEVEL-II

| No. of Households | Winter |  | Summer |  |
|-------------------|--------|--------|--------|--------|
|                   | No. of residents | MSW (kg) | No. of residents | MSW (kg) | No. of residents | MSW (kg) |
| 1                 | 6      | 17.060 | 6      | 17.746 | 6      | 18.498 |
| 2                 | 5      | 15.238 | 5      | 17.322 | 5      | 17.842 |
| 3                 | 4      | 8.656  | 4      | 13.872 | 4      | 14.320 |
| 4                 | 6      | 14.502 | 6      | 18.996 | 6      | 14.544 |
| 5                 | 5      | 13.315 | 5      | 14.036 | 5      | 17.504 |
| 6                 | 6      | 14.054 | 6      | 17.762 | 6      | 19.402 |
| 7                 | 6      | 15.636 | 6      | 15.944 | 6      | 17.168 |
| 8                 | 5      | 13.639 | 5      | 18.826 | 5      | 18.990 |
| 9                 | 7      | 18.110 | 7      | 22.729 | 7      | 22.102 |
| 10                | 5      | 14.201 | 5      | 16.723 | 5      | 18.943 |
| 11                | 5      | 15.119 | 5      | 18.269 | 5      | 19.760 |
| 12                | 6      | 17.174 | 6      | 19.150 | 6      | 19.000 |
| 13                | 5      | 16.972 | 5      | 16.001 | 5      | 18.927 |
| 14                | 6      | 18.762 | 6      | 20.160 | 6      | 20.994 |
| 15                | 5      | 15.116 | 5      | 17.691 | 5      | 19.698 |
| **Total**         | 82     | 227.554| 82     | 264.777| 82     | 277.692|

**Total No. of Samples** | 85 | 85 | 85

## (c) ECONOMIC LEVEL-III

| No. of Households | Winter |  | Summer |  |
|-------------------|--------|--------|--------|--------|
|                   | No. of Residents | MSW (kg) | No. of Residents | MSW (kg) | No. of Residents | MSW (kg) |
| 1                 | 7      | 17.376 | 7      | 18.206 | 7      | 20.050 |
| 2                 | 4      | 9.724  | 4      | 14.954 | 4      | 10.226 |
| 3                 | 5      | 12.370 | 5      | 15.424 | 5      | 11.656 |
| 4                 | 4      | 10.370 | 4      | 13.312 | 4      | 10.136 |
| 5                 | 6      | 13.142 | 6      | 16.038 | 6      | 12.756 |
| 6                 | 8      | 17.140 | 8      | 18.014 | 8      | 21.778 |
| 7                 | 7      | 16.248 | 7      | 16.634 | 7      | 19.914 |
| 8                 | 5      | 17.600 | 5      | 18.206 | 5      | 18.180 |
| 9                 | 4      | 8.226  | 4      | 12.694 | 4      | 11.812 |
| 10                | 5      | 12.068 | 5      | 14.971 | 5      | 12.792 |
| 11                | 6      | 11.267 | 6      | 15.469 | 6      | 11.790 |
| 12                | 5      | 8.496  | 5      | 15.416 | 5      | 13.049 |
| 13                | 7      | 17.140 | 7      | 18.970 | 7      | 22.197 |
| 14                | 7      | 16.248 | 7      | 19.065 | 7      | 19.197 |
| 15                | 6      | 16.159 | 6      | 16.669 | 6      | 18.216 |
| **Total**         | 86     | 203.574| 86     | 244.042| 86     | 233.749|

**Total No. of Samples** | 85 | 85 | 85
The total solid waste against 765 samples was found to be 2141.211 kg. The average annual composition value for MSW per capita were determined considering a weighted mean of all the seasons i.e. winter, summer and spring at varying temperature from 5 °C in winters to as high in summers during June July as 47 °C. The results illustrate that Level I people with highest income generates highest amount of solid waste; 2.40 kg/capita/day in winters, 3.35 kg/capita/day in spring and 3.70 kg/capita/day in summers. For level II, the average annual waste generation for three different seasons i.e. winter, spring and summer was varying from 2.77 kg/capita/day, 3.22 kg/capita/day and 3.38 kg/capita/day respectively. For level III, the average annual waste generation for three different seasons i.e. winter, spring and summer was varying from 2.36 kg/capita/day, 2.83 kg/capita/day and 2.71 kg/capita/day respectively. The seasonal difference of MSW generated per capita among three levels was not so significant. Figure. 2 shows the waste generated per capita in Jammu city. The average weighted waste per capita generated for the three seasons of a year was found to be 3.15 kg/capita/day, 3.12 kg/capita/day and 2.63 kg/capita/day. In winter’s seasons, the amount of waste per capita was less among all three levels of income. This may be due to the reason that less drinks, fresh foods and vegetables are consumed which ultimately leads to lesser waste generation. Waste generation most of which was organic was the highest in summer season.

**Figure 2.** Waste generated per capita in Jammu City.

4.1 Characterization of Municipal Solid Waste

The average amount of MSW generated per capita per day for each economic level i.e. I, II and III was 3.15, 3.12 and 2.63 kg per capita per day. Organic fraction was found to cover most of the waste generated in Jammu city. Spring season has most of the organic waste followed by winter and then the summer in Economic Level-I. The difference however was not too much. Level I (highest income) consists of high food waste which was generally uneaten and the one which was bought commercially. The percentage of papers and cardboards were found higher in summer season from Level I and II. This may be due to the reason that in summer, most of the people are at home due to summer vacations. However, the cardboards were more in Economic Level – I because of high standard of living of people in this area who generally buy products from markets in cardboards.

Plastic waste was at the higher side in summer season for Economic level II and III. However, economic Level I (winter season) was generating more plastic waste and this may be due to the fact that most of the things are prepared at home by people of this class which leads to less consumption of plastic materials. The reason for plastic waste is being more in summer is that plastic products are utilized for drinking water, juice, dairy products etc. Metal in the form of batteries were found in fractions in all the economic levels and in all seasons. They are generally disband because there is
no proper collection system of these batteries in Jammu. Glass fiber was also found in fraction such as wine and food bottles etc. but whatever percentage of fiber was found it was maximum in winter season. As for the other fraction, which consists of clothing, toys, fabric, and textiles hairs etc., the quantity was marginal. These things are commonly being sold as recycled things. Huge things like electronic items, furniture etc. are not considered for the study as such things are gathered on specific days allotted by the Urban Sanitation Service. These are dumped at the landfill sites where they are dismantled by the rag pickers and further sold in pieces.

Figure 3 shows the waste composition results in terms of percentage weighted for all the three seasons for three different socio-economic levels. The organic waste has the highest amount of waste generated in all three level I, II and III with composition of 80%, 79% and 87% respectively followed by combination of paper and cardboard which was almost equal i.e. 8.50%, 8.79% and 8.59% respectively. Plastic was found to be maximum in Economic level II with percentage of 8.56% followed by economic level I of 8.45% and at last the level III with 6.96% of plastic. Rests of the wastes were found in very less amount and almost equal to each other. The characterization values for the weighed MSW is shown in figure, the organic fraction is the highest with 82.73% followed by the plastic waste with 7.98% and then the combination of paper and cardboard with 6.78%.

**Figure 3.** Average percentage of the six waste fractions generated from three socio-economic levels in Jammu city, India.
4.2 Municipal Solid Waste Management
The key purpose of characterizing the MSW was to know how the waste generated by different socio-economic classes in different seasons of the year can be managed so that pollution in the form of water and air can be controlled to some extent. The results presented in Figure 5 revealed that three methods viz. Recycling, Landfilling and Incineration can effectively be used for management of the MSW in Jammu city. Plastic bottles, paper, cardboard, metals, glass, plastic bags etc. can easily be recycled thus reducing the utilization of new raw materials, reducing energy consumption, reducing air pollution from burning of waste and reducing water pollution from landfill sites [13-14]. However, where it is not possible to recycle the waste then either landfilling by properly disposing the solid waste or incineration may be used. Figure 5 shows the percentage of recyclable waste and the one which should be disposed of scientifically by landfilling or incineration.

Figure 4. Characterization of municipal solid waste in Jammu city, India.

Figure 5. Percentage of MSW managed by Recycling, Land filling and incineration.
5. Conclusion
Municipal solid waste generated in Jammu city was determined at three different levels income at three different seasons of year viz winter, spring and summer. 2141.211 kg waste was found to be generated from 765 samples in 45 households during three seasons of a year. The results showed that group with high level of income i.e. Economic Level-I was generating more with 2.40 kg/capita/day in winters to 3.70 kg/capita/day in summers. For EL-II and EL-III, the average annual waste generation for three different seasons was varying from 2.77 kg/capita/day to 3.38 kg/capita/day and 2.36 kg/capita/day to 2.71 kg/capita/day, respectively, indicating that generation of waste is more in summers followed by spring and then there was a slight decrease in waste generation in winters. The organic waste has the highest amount of generation in level I, II and III with 80 %, 79 % and 87 % respectively followed by combination of cardboard and paper which was almost equal i.e. 8.50 %, 8.79 % and 8.59 %, respectively. Plastic was found to be maximum in Economic level II with percentage of 8.56 % followed by economic level I of 8.45 % and at last the level III with 6.96 % of plastic. Rests of the wastes were found in very less amount and almost equal to each other. The characterization values for the weighed municipal solid waste shows organic fraction of 82.73 % followed by the plastic waste with 7.98 % and then the combination of paper and cardboard with 6.78% rest of the wastes were found in traces. It was also suggested that out of the waste generated in Jammu city 82.73 % can be managed by either landfilling or incineration and rest 17.27 % can be managed by Recycling it.

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