Municipal Solid Waste Composition Analysis: Amman City case study

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Abstract

The aim of this paper is to establish up-to-date waste composition data for Amman City as part of the implementation of "The Development of a Long-Term Strategic Plan Improving Amman Municipal Solid Waste Management System" Project.

In Jordan, the amount of household solid waste produced per capita and day ranges, according to a previous study conducted by Royal Scientific Society (RSS) in 2009, between 0.7 kg and 1.0 kg depending on the regions classification and lifestyle.

A municipal solid waste (MSW) in Jordan includes a mix of domestic garbage, plastics, glass, in addition to hazardous and non–hazardous medical and industrial solid wastes in some cases. Sorting at source of different types of solid waste is not practiced in Jordan and considerable amounts of recyclable materials are sent to final disposal sites (dumpsites or landfills). Contractors separate and collect metals, plastic and cardboard at final disposal sites. Their work is inefficient and imposes adverse impacts on their health; also scavengers pick up some valuable materials from the containers on the streets, which impose a health problem to them and to the public.

A ten months study during the four seasons (summer, autumn, winter and spring) from August 2010 to May 2011 was conducted by the RSS team to identify waste composition, chemical and physical characterization (moisture content, calorific value, volatile matter and density) of 16 different sample streets that are distributed in 8 regions of Amman City and represent 5 different lifestyle categories (3 residential categories: high(A), medium (B) and public (C) lifestyle, in addition to another two categories: commercial (D) and industrial (E)), which cover more than 35% of the population of Jordan. The period of the events which could affect the composition of the solid waste were excluded during this study.

The results of the study show that about 50% (wt) of the MSW is organic. The other solid waste constituents are: plastic, cardboard and paper which comprise about 31% of the total solid waste, in addition to other 19% which consists of hygienic textile, combustible and incombustible waste, etc. The plastic was also sorted to different sub-categories according to the type of the plastic. The analysis of the MSW shows that there is a correlation between the lifestyle and the life-activities and the solid waste composition of the area.

1. Introduction

Jordan has a population of about six millions with an annual growth rate of 2.2%, two millions of them are living in the area covered by this study which consists of urban areas only. The whole study area is covered by a mechanism to collect the solid waste which then is transported to Al-Ghabawi landfill which is the only sanitary landfill in Jordan and serves most areas of Amman and Zarqa. About 2500 tons per day of solid waste are dumped in this landfill (about 50% of the total amount of solid waste of Jordan).

Increasing of population growth and changing the lifestyle of people in Jordan will increase the amount of waste produce per capita and day if no long-term municipal solid waste management plans are developed and applied in the near future which will then produce tremendous problems to public health and environment.

The main objectives of the project are to strengthen the operational, financial and environmental performance of municipal solid waste management in Amman, and to improve MSW collection, transfer, treatment and disposal with possible resource recovery and recycling elements as might be deemed cost-effective, private sector participation and other procurement-related activities.

The essential step of the successful planning for MSW management program is the availability of reliable information about the quantity and the type of the waste materials being generated which can

be useful for the waste management developers. Effective waste management through MSW composition studies is important for numerous reasons, including the need to estimate material recovery potential, identify sources of component generation, facilitate design of processing equipment, estimate physical, chemical, and thermal properties of the waste, and maintain compliance with national law and international directives. The composition of generated waste is extremely variable as a consequence of seasonal, lifestyle, demographic, geographic and legislation impacts. This variability makes defining and measuring the composition of waste more essential for long-term urban development planning.

This paper presents the results of the MSW analysis study in Amman city which consists of 26 different administrative zones. The study was carried out by Environmental Management Studies Division (EMSD) at Royal Scientific Society (RSS). The study based on the field work of collection of the MSW and sorting of it according to the international standards using the French Standard Method; MODECOM^{TM}, which is adapted from The French Agency for Environment and Energy Management (ADEME). Different laboratory tests were conducted to the waste samples according to international standards such as: ASTM E790 – 08: "Standard Test Method for Residual Moisture in a Refuse-Derived Fuel Analysis Sample", ASTM E240: "Heat of Combustion Liquid Hydrocarbon Fuels by Bomb Calorimeter" and ASTM E897-88: "Volatile Matter in the Analysis Sample of Refuse-Derived Fuel".

16 sample streets that are distributed in 8 regions of Amman city and represent 5 different lifestyle categories; 3 residential, one commercial and one industrial workshops area were investigated during the study. The analysis was repeated in each of the four seasons (summer, autumn, winter and spring) from August 2010 to May 2011.

2. Methodology

To evaluate the differences in domestic waste generation inside the different 26 administrative zones of Amman, representative regions were selected as well as representative streets in these regions were selected. The criteria for the selection were the type of region: residential, commercial and industrial (workshops). Inside the residential regions the criteria were the type of lifestyle: high, medium and public. In each residential region two representative areas were selected and in each area two representative streets were selected, while in commercial and industrial regions two representative areas for each were selected and one representative street was selected.

The collection of the waste from each selected street was done from the source of generation directly (garbage containers or bins) and taking into consideration that the collected solid waste shall not be mixed with other streets and shall not be compacted. The amount collected from each street was equivalent to 4 containers of capacity 1100 L which is equivalent to about 500 kg.

In a transfer station in Amman, the sorting process was performed after weighing the solid waste in a known volume containers to calculate the density of the non-compacted solid waste. The solid waste was size sorted using a sorting table for size distribution which consists of 4 boxes; the first box with a circular mesh of 100 mm, the second box with a circular mesh of 60 mm, a third box with a circular mesh of 20 mm and the final box is a recuperation box without holes. All the waste which did not pass the first box was classified as large, while all the waste passed the first box and did not pass the third box was classified as medium and finally the waste passed the third box was classified as fine. The large waste was sorted into 13 different waste categories (large size). The medium was also sorted into 13 different waste categories (medium size). The fine waste was considered as organic waste. The 13 different waste categories are: organic, paper, cardboard (corrugated), complex, plastic, textile, metal, aluminium, glass, special (hazardous), hygienic textile, combustible and incombustible waste. Plastic was sorted into sub-categories (PET: polyethylene terephthalate, PE: polyethylene, PVC: polyvinyl chloride, PP: polypropylene, PS: polystyrene, Film), metal into ferrous and non-ferrous and aluminium into cans and foils.

Moisture content was measured according to the standard "ASTM E790 – 08" method. This test was done for each collected sample per size distribution (large, medium and fine) for the following categories: organic, paper, cardboard, complex, plastic, metal, aluminium, glass, hygienic textile, combustible (including textile) waste and incombustible waste.

Energy content was measured by using the standard "ASTM E240" method, while volatile matter was measured by using the standard "ASTM E897-88". These measurements were done for the following categories for samples contain 2/3 from the "Large" and 1/3 from the "Medium" waste, in addition to one sample from the fine organic: organic, paper, cardboard, complex, plastic, hygienic textile and combustible waste (including textile).

3. Results

Figure (1) below shows that organic, plastic, cardboard, paper, hygienic textile and combustible wastes are in average constitute 91.0% of total MSW (49.7% organic, 15.7% plastic, 8.1% cardboard, 6.6% paper, 5.6% hygienic textile and 5.3% combustible). Glass waste constitutes 2.6% and textile waste constitutes 2.3% of MSW. Incombustible waste constitutes 1.2%, while complex waste constitutes 1.0%. Metal, special and aluminium waste are considered low with a weight percentage of less than1% for each.

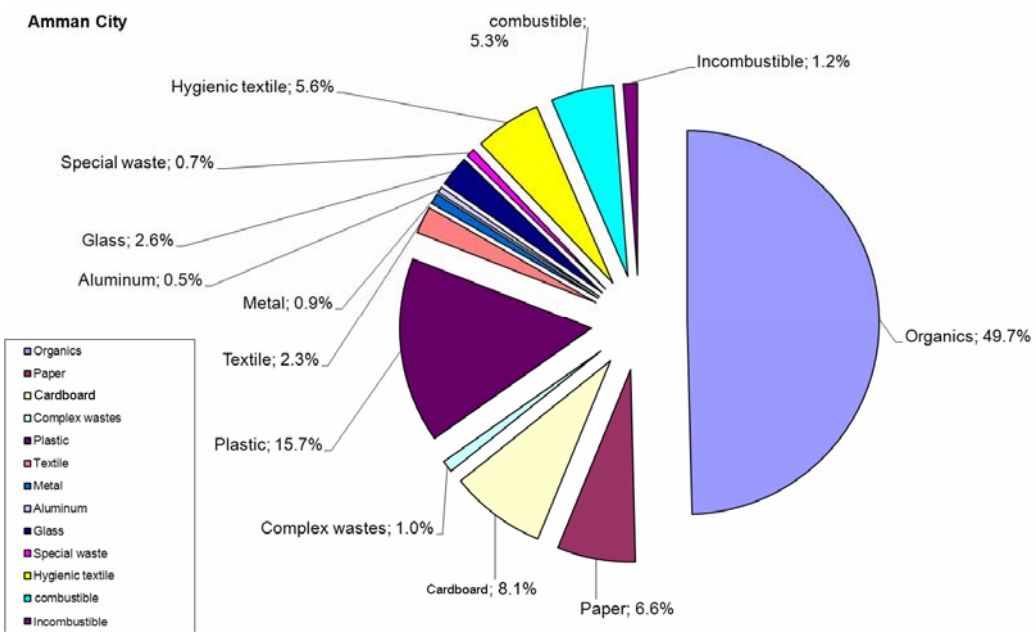

Figure 1: Mean weight percentage [%] of waste composition of Amman City

The values of the mean density of the solid waste - without compaction - for each season ranges from 111.2 kg/m^3 in autumn to 149.8 kg/m^3 in winter with an average for the whole year of 130.9 kg/m^3.
The average results of the moisture content of the waste categories (organic, paper, cardboard, complex, plastics, metal, aluminium, glass, hygienic textile, combustible including cloth textile and incombustible) for all the sample streets for each season are shown in Figure (2).

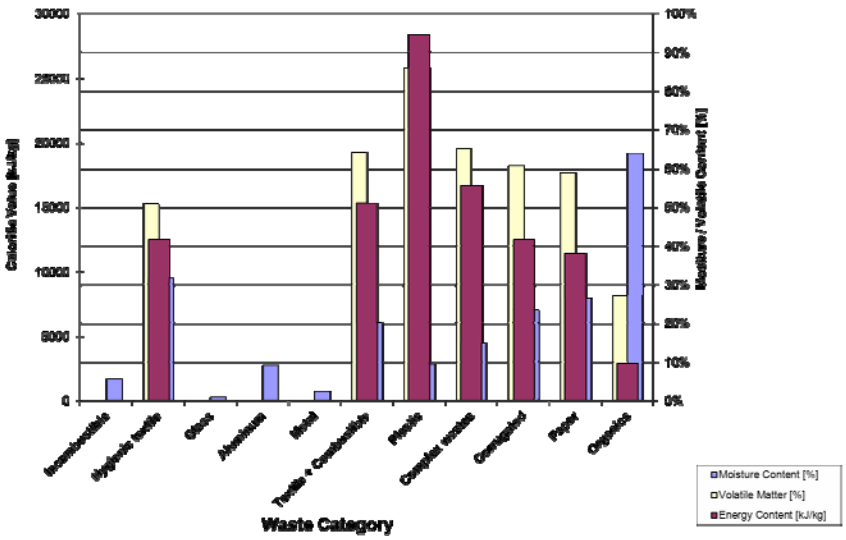

Figure 2: Mean moisture, volatile content and calorific value of each waste category of Amman City

The average weight percentages of different waste categories in the different seasons and the average for the whole year can be seen in Figure (3) below. The values for different seasons are in general similar during except for some waste categories.

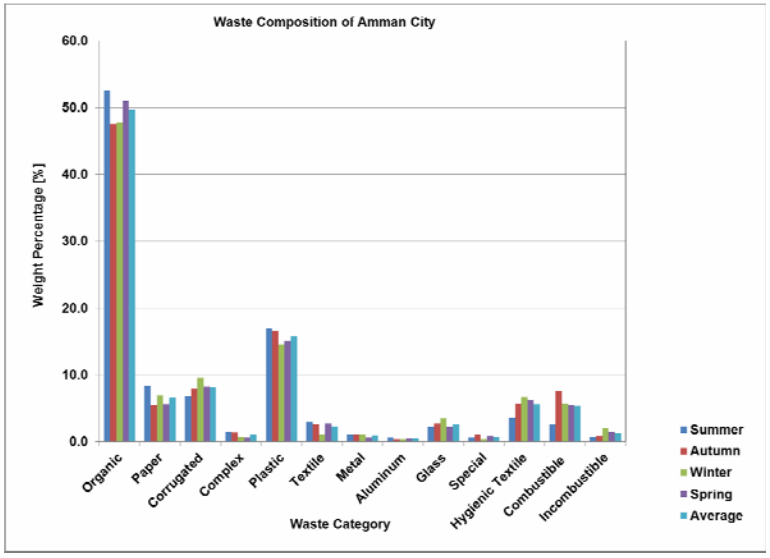

Figure 3: Waste composition of Amman City in the four different seasons

Figure (4) below shows the mean weight percentages of the 13 different waste categories for the whole year according to the five different lifestyle categories (A, B, C, D and E). It is noticed that the MSW composition can vary according to the lifestyle and the activities exiting in a region.

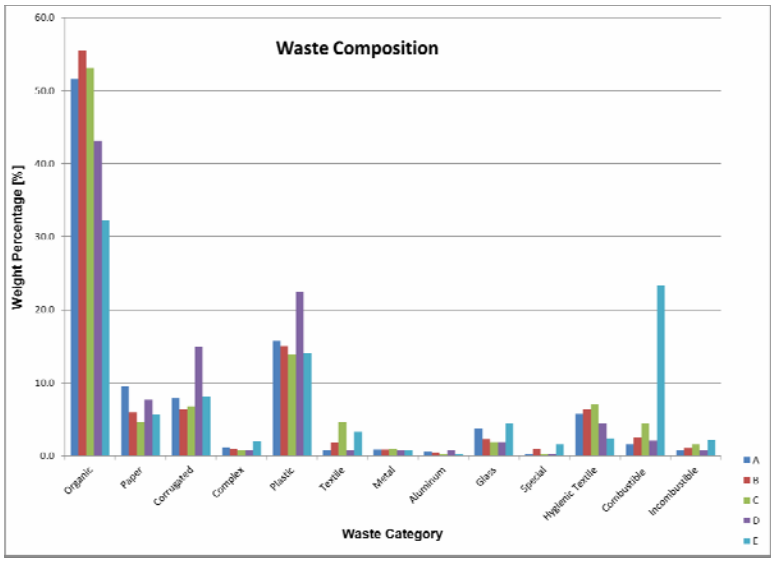

Figure 4: Waste composition of Amman City (average of the four seasons) in the five different lifestyle categories

The size distribution results of MSW are shown in Table (6) below. The results show that 65.8% of the municipal solid waste of all streets (as an average value) has large size (> 100 mm), and about 34% of the waste has medium size (20 – 100 mm), while only 0.2% of the MSW has small size (< 20 mm). The weight percentages of the different waste sizes in different seasons are in general similar.

Table 1: Size distribution of the waste samples during the four seasons

Season	Large	Medium	Fine
Summer	a	a	a
Autumn	59.4	40.2	0.4
Winter	65.8	34.0	0.1
Spring	72.1	27.7	0.2
Average	65.8	34.0	0.2

a: no waste size distribution was done due to technical reasons

The mean values of the weight percentage of the categories and sub-categories for each of plastic, metal and aluminium waste that were sorted in all sample streets in four seasons are shown in Table (2).
The average weight percentage for the whole year of polyethylene (PE) (film and containers) is about 15.1% of the total large size solid waste and is about 71.6% of the plastic waste (in the large size fraction of MSW). Polyethylene tetra-phthalate (PET) types of the plastic material constitute about 3.2% of the total large size solid waste of the whole year and about 15.2% of the plastic waste. Polystyrene constitutes about 2.1% of the total large size solid waste of the whole year, and 10% of the plastic

waste. From Table (5), it can be seen that the weight percentages of plastic waste sub-categories are similar, except for small deviation.
The ferrous metal is 100% of metal waste, and constitutes in average for the whole year a low percentage of the total large size municipal solid waste (1.2%). The ferrous metal weight percentage is higher in autumn and winter than in spring and summer.
The average weight percentage for the whole year of the aluminium cans is about 76.8% of the aluminium waste in the large size fraction, while the weight percentage of the aluminium foils is about 23.2% of the aluminium waste in the large size fraction, but both of them constitute about 0.56% of the total large size MSW. The aluminium cans weight percentage is higher in autumn than in winter and spring, and in summer is less than in all other seasons.

Table 2: Weight percentages of the waste sub-categories of the sorted large sample.

Season	Weight [%]													
	Plastic								Metal			Aluminium		
	Tot	Film	PET	PE	PP	PVC	PS	other	Tot	Ferr	Non-Ferr	Tot	Can	Foil
S	18.5	12.7	3.2	1.1	0.2	0.3	1.0	0.0	0.8	0.8	0.0	0.4	0.3	0.1
A	26.1	16.4	4.7	1.4	0.3	0.0	2.9	0.4	1.6	1.6	0.0	0.7	0.6	0.1
W	21.2	14.0	2.6	0.9	0.6	0.0	2.5	0.6	1.4	1.4	0.0	0.6	0.4	0.2
P	18.5	13.0	2.4	0.9	0.1	0.0	1.9	0.2	0.8	0.8	0.0	0.5	0.4	0.1
A	21.1	14.0	3.2	1.1	0.3	0.1	2.1	0.3	1.2	1.2	0.0	0.56	0.43	0.13

S: Summer, A: Autumn, W: Winter, P: Spring, A: Average

4. Discussion and evaluation of results

By comparing the average weight percentages of different waste categories in the different seasons, as it can be seen in Figure (3), are in general similar during the whole year except for some cases, such as: the complex waste weight percentage is higher in summer and autumn than in winter and spring, which could be due to the fact that more drinks are consumed during summer and autumn because of the higher weather temperatures. Another example is the weight percentage of combustible waste is higher in autumn than in other seasons, which could be due to the higher amount of old vehicle tires, since a lot of people change the tires of their vehicles before the beginning of winter season. The composition of metal and aluminium wastes in the MSW is very low during the whole year even in industrial areas, which is due to the scavengers activity in different regions.
PE (film and containers) has the highest weight percentage of plastic sub-categories as can be seen in Table (2), which could be due to the extensive use of plastic packaging materials such as plastic films (HDPE and LDPE).
PET is in the second place after PE, which could be mainly due to the use of bottles for drinking water and other soft drinks. PET weight percentage is a little bit higher in summer and autumn than in winter and spring, which could be related to the fact that the people consume more soft drinks and bottled water in summer and autumn than in winter and spring.
The ferrous metal weight percentage is higher in autumn and winter than in spring and summer, which could be related to fact that the people consume more canned food in autumn and winter, because less fresh food is available in these two seasons, since most of the ferrous metal waste was food cans.
The aluminium cans weight percentage is higher in autumn than in winter and spring, and in summer is less than in all other seasons, which could be related to the fact that people consume more soft drinks in hot seasons than in cold ones, but since the Holy month of Ramadan came in summer, so the aluminium cans are less in summer, in addition to the fact that the scavengers are more active in

collecting the cans, since the weather conditions are better for them in summer especially they are working during nights.
The weight percentage of the large size waste was higher in spring than in the other seasons as can be seen in Table (1), which could be due to large amounts of yard waste in spring season.
It is noticed that the municipal solid waste composition can vary according to the lifestyle and the activities exiting in a region as shown in Figure (4). For example, the weight percentage of paper waste in category A, which is a high lifestyle residential area, is 9.5%, which is higher than that in the other two different residential lifestyle areas (5.9% and 4.6% for B and C respectively). This could be justified by the fact that the people of the high lifestyle areas buy more printings than the others. Also, the plastic and corrugated waste is higher in category D (commercial) than in other areas, due to the packaging of wares. The organic waste weight percentage in category E (industrial) is the lowest in comparison with the other categories (residential and commercial), which could be due to the fact that in industrial areas less families are living and less yards are available which may produce more organic waste.
The mean density of the solid waste - without compaction – varies through the seasons, since it depends on the composition of the solid waste. The organic and incombustible wastes increase the density of the waste sample, in addition to the glass waste.
The moisture content in summer is less than that in the other seasons due to the weather conditions of high temperature which leads to high evaporation rate and due to no rain.
As shown in Figure (2), organic waste has the highest moisture content (63.86%) and the lowest calorific value (2858 kJ/kg) and volatile matter (27.16%), while the plastic waste has the lowest moisture content (9.41%) and the highest calorific value (28362 kJ/kg) and volatile matter (86.01%).

5. Conclusion

The analysis of the municipal solid waste in 5 different categories, which represent different lifestyles, 8 areas, and 16 sample streets shows that there is correlation between the lifestyle and the life-activities and the solid waste composition. The study covered the four seasons of the year, since each sample street was studied four times during the year (i.e. one time during each season).
During the period of the study, some events were happened, such as: the Holy month of Ramadan during the summer season (August and September), which could have effects on the waste composition, and the sorting of the solid waste was carried out for some streets during Ramadan according to the request of Greater Amman Municipality. During the autumn season two events were happened; Parliament Elections and Eid Al-Adha which could affect the composition of the waste, but the sampling of the waste avoided these two events to give more representative results.
Some of the days of the solid waste sampling were rainy which could affect the moisture content of the waste. The high moisture content of waste can lower the calorific value of the solid waste and increase the leachate content in the landfill, so it is recommended to have waste containers with covers to protect the waste from rain, in addition to other main benefits of such covers, such as: reduce the dispersion of waste odors and reduce the attraction of the insects. The calorific value is in general inversely proportional to the moisture content of the waste. Therefore, the calorific value for the plastic waste shows higher value than the organic waste.
It is recommended to make more efforts on sorting the solid waste at source, at least beginning with some waste categories, such as cardboard waste, which is already sorted in many areas from the source by the shops which generates this type of waste in large quantities, so it should be taken into consideration that the real weight percentage of the cardboard waste in the solid waste of Amman City is higher than the results in this study, as well as the weight percentages of metal, aluminium and plastic (containers) waste which are collected by the scavengers from the waste containers at the streets. Also, it is recommended to have two types of containers at each collection point (at the present locations of waste containers): one for the organic waste and another for all other types of waste, so the moisture content of all other types of waste will be lower and the waste will be cleaner, as well as to study all alternatives of treating the different waste categories which is suitable to Amman City.

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