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# Generation and Composition of Municipal Solid Waste (MSW) in Muscat, Sultanate of Oman

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## Abstract

The success of waste management requires accurate data on generation and composition of waste which is pivotal for the decisions towards the appropriate waste management system. At present there is no data available on Municipal Solid Waste (MSW) generation and composition collected systematically in Oman. Hence, this preliminary study was conducted in Al-Multaqaa landfill, the only engineered landfill functioning in Oman. The main objective of this study is to determine the generation rate and composition of municipal solid waste with the intention of providing base line data for development of municipal solid waste management system. The samples were collected from the landfill in two different seasons, in summer and winter. The collected sample was sorted out into various components. Subsequently, the weight and volume of each component were measured and recorded. The daily generation of MSW works out to be 0.97 Kg/day/person by weight,  $3.113 \times 10^{-3} \text{ m}^3/\text{day/person}$  by volume with a density of  $311.73 \text{ Kg/m}^3$ . The study results reveal that the MSW stream has the largest proportion of biodegradable and recyclable waste. If waste management options such as composting, recycling and energy recovery are to be practiced in the future, there is a greater possibility of reducing substantial amount of waste stream getting disposed to the landfill.

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## 1. Introduction

Due to the fast economic development and urbanization, the generation of municipal solid waste (MSW)

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has rapidly increased worldwide and the composition of MSW has also changed significantly. These changes bring more pressure on the existing environment, human health and also to the management of MSW system [1], [2]. Generally, increased population growth and rising consumer choices have resulted in a larger production of waste worldwide [3]. The sources of MSW are primarily classified into residential, institutional and commercial waste [4], [5]. The characteristics and composition of MSW depends on the topography of the area, seasons, food habits and commercial status of the city etc. [6]. Solid waste needs to be characterized for source, generation rates, type of wastes produced and composition, in order to monitor, control and to improve prevailing waste management systems. All the important information related to sources, quantity and composition are very important for the design and operation of the functional elements related to waste management. The functional elements include waste generation, on-site handling and storage, collection, transfer and transport, processing and recovery, recycling and reuse, treatment and final disposal. The reliable estimates of MSW generation are vital for effective waste management planning and help taking better financial, regulatory and institutional decisions [7].

The gulf regions have the highest per capita waste generation across the world. The total volume of solid waste generated in GCC region is approximately 120 million tons per year, in which MSW is the second largest waste category by source [8]. Muscat is the capital and most important city in the Sultanate of Oman. The modern developments in the residential, commercial and industrial sector have extended the city limits into surrounding areas. Recently townships connected with highways and modern utilities witnessed growth on economic development, industrialization, urban sprawl and commercial activities [9]. The increase in population had created an increase in waste generation by more than 4 folds from 257,004 tons in 2001 to 1,343,486 tons in 2009 [10]. At present, there is no systematically collected data or information available in Oman regarding solid waste composition and characteristics. Hence, it is essential to study the composition and characteristics of solid waste, which will help in improving solid waste management strategies and consequently reducing many environmental impacts. Hence an attempt was made to study the generation and composition of MSW from Al-Multaqaa landfill, the only engineered landfill functioning in Oman.

## **2. Materials and Methods**

### *2.1. Study area and design*

The samples were collected from Al-Multaqaa landfill in two different seasons. Sampling was carried out three times on a fortnight interval for each season, i.e., January & February during winter and May & June during summer to represent respective seasons. The Al-Multaqaa landfill for MSW disposal is situated in the Wilayat (District) of Al-Amerat, Muscat governorate, Sultanate of Oman. Initially, the Municipal solid waste sample was collected from four different directions at randomly selected locations of the waste piles, where waste was offloaded by the heavy trucks from transfer stations. Following an earlier work [6], approximately 20 kg of so collected sample was subjected to reduction of the sample quantity to 5 kg using quartering technique without compromising the prevailing composition of solid waste components. Then the reduced sample was sorted out manually into various components. Subsequently, the weight and volume of each component were measured and recorded. The total density is calculated by dividing total weight by total volume which amounts to the average density of MSW.

### *2.2. Determination of rate of generation of MSW*

The per day generation rate was calculated from the daily quantity of waste arriving at the landfill facility which was obtained from the concerned municipal authority. Based on the total weight of waste disposed in

the landfill in a day and the total population of the community from where the waste is generated, the per capita generation of MSW was determined.

$$PCG = \frac{[Waste\ generated / day]}{Population} \quad (Kg / day / person)$$

Where, PCG is the per capita waste generation [11].

### 3. Results and Discussion

#### 3.1. Generation of Municipal solid waste in Muscat(Al-Multaqaa landfill)

Since this study was carried out in Al-Multaqaa landfill situated in Al-Amerat, the generation rate of MSW is calculated based on the records of the total waste reaching the landfill every day for disposal. The landfill is handling about 750 tons of waste daily as per the record maintained by the authority. The waste to this landfill is coming from various Wilayat (District) including Muscat, Muttrah, Bowshar, Al Seeb, Al-Amerat and Qurayyat. The total population of Muscat Governorate is 775,878[12]. According to this study, the rate of waste generation in this region is 0.97 kg/day/person by weight and  $3.113 \times 10^{-3} m^3/day/person$  by volume. The average density of MSW is  $311.73 kg/m^3$ . This value in comparison is within the generation rate reported in other developing countries. As per GCC report in 2004[13] MSW generated (kg/ capita/day) in Oman is 0.70. Now may be due to economic growth, accelerating population growth and changes in the life style pattern, the country has shown increment in MSW generation. A prediction on the rate of municipal solid waste generation in Arab Region, in the Year 2020, shows that the value simply exceeds 200 million tons per year. It is of importance to indicate the obvious correlation between the per capita income and the rate of solid waste generation, i.e., higher GDP causes higher waste generation. [14].

#### 3.2. Composition of Municipal solid waste

In this study, 14 different fractions of waste have been segregated in the collected sample. The major one is organic waste which accounts for 71.20% and 65.80% of the total MSW collected during the winter and summer respectively. On the other side, the inorganic fraction accounts for 28.80% and 34.20% in winter and summer respectively. The results clearly indicate that the composition of organic waste is dominated by food waste (mixed). It mainly includes leftover food residue, vegetable waste, leaves and decayed vegetables, which accounts for 33.60% by weight and 16.70% by volume in winter and 22.80% by weight and 7.83% by volume in summer. Previous studies have reported that large portion of solid waste in developing countries is food waste [15], [16]. Table 1 and 2 show the MSW composition in winter and summer season. The results indicate that the weight and volume of the food waste are approximately 10 percent higher in summer than in the winter. From the results, it is clear that in Oman huge quantities of food waste is generated from household and commercial establishments like restaurants and hotels.

Table 1. Municipal solid waste composition in winter season

Sl. No.	Composition	Weight (Kg)	% Composition by Weight	Volume ( $\times 10^{-3} \text{m}^3$ )	% Composition by Volume	Density ( $\text{Kg/m}^3$ )
<b>Organic:</b>						
1	Food waste (Mixed)	1.68	33.60	2.63	16.70	638.78
2	Inert matter	0.28	5.60	0.48	3.05	583.33
3	Paper & Cardboard	1.26	25.20	3.28	20.83	384.15
4	Textile & Gunny Bags	0.26	5.20	1.24	7.87	209.68
5	Wood	0.08	1.60	0.12	0.76	666.67
<b>Total</b>		<b>3.56</b>	<b>71.20</b>	<b>7.75</b>	<b>49.21</b>	<b>459.35</b>
<b>Inorganic:</b>						
1	Construction waste	0.01	0.20	0.004	0.02	2500.00
2	Glass	0.40	8.00	0.69	4.38	579.71
3	Leather	0.02	0.40	0.02	0.12	1000.00
4	Metal-Ferrous	0.12	2.40	0.48	3.04	250.00
5	Metal-Non Ferrous	0.02	0.40	0.17	1.08	117.65
6	Other plastics	0.06	1.20	0.72	4.57	83.33
7	Plastic bags	0.59	11.80	2.66	16.88	221.80
8	Plastic container	0.17	3.40	2.75	17.46	61.82
9	Thermocole	0.05	1.00	0.51	3.24	98.04
<b>Total</b>		<b>1.44</b>	<b>28.80</b>	<b>8.00</b>	<b>50.79</b>	<b>180.00</b>
<b>Grand Total</b>		<b>5.00</b>	<b>100.00</b>	<b>15.75</b>	<b>100.00</b>	<b>317.46</b>

The huge quantity of organic waste present in the MSW stream has the potential to cause environmental problems and at the same time has a great potential for resource recovery. The quality of leachate in the landfill depends on quantity of organic waste fraction disposed. More the organic fraction, the higher will be the biochemical oxygen demand (BOD) of leachate. The amount of landfill gas produced in a sanitary landfill also depends on the quantity of organic fraction present in the MSW. However, a waste stream with a high organic content can be processed to produce high quality compost and thus is advantageous [17].

Table 2. Municipal solid waste composition in summer season

Sl. No.	Composition	Weight (Kg)	% Composition by Weight	Volume ( $\times 10^3 \text{ m}^3$ )	% Composition by Volume	Density $\text{Kg/ m}^3$
<b>Organic:</b>						
1	Food waste (Mixed)	1.14	22.80	1.28	7.83	890.63
2	Inert matter	0.41	8.20	0.64	3.91	640.63
3	Paper & Card board	1.62	32.40	6.50	39.76	249.23
4	Textile & Gunny Bags	0.01	0.20	0.47	2.88	21.28
5	Wood	0.11	2.20	0.20	1.22	550.00
<b>Total</b>		<b>3.29</b>	<b>65.80</b>	<b>9.09</b>	<b>55.60</b>	<b>361.94</b>
<b>Inorganic:</b>						
1	Construction waste	0.13	2.60	0.30	1.83	433.33
2	Glass	0.43	8.60	0.39	2.38	1102.56
3	Leather	0.07	1.40	0.31	1.90	225.81
4	Metal-Ferrous	0.15	3.00	0.16	0.98	937.50
5	Metal-Non Ferrous	0.08	1.60	0.19	1.16	421.05
6	Other plastics	0.18	3.60	1.01	6.18	178.22
7	Plastic bags	0.33	6.60	1.63	9.97	202.45
8	Plastic container	0.32	6.40	2.92	17.86	109.59
9	Thermocole	0.02	0.40	0.35	2.14	57.14
<b>Total</b>		<b>1.71</b>	<b>34.20</b>	<b>7.26</b>	<b>44.40</b>	<b>235.54</b>
<b>Grand Total</b>		<b>5.00</b>	<b>100.00</b>	<b>16.35</b>	<b>100.00</b>	<b>305.81</b>

The second most represented waste component in Al-Multaqaa landfill is paper, which is made up of paper packages (cardboard and combined packages) and prints (newspapers, magazines and books). This accounts for 25.20% by weight and 20.83% by volume in winter and 32.40% by weight and 39.76% by volume in summer. Similar results were found in Bakri landfill in Malaysia [5]. The higher generation of paper and cardboard waste is due to various reasons. In Oman there is no practice of rag picking for collecting waste papers. All the waste papers are used to get disposed into trash instead of sorting out at the points of generation. Another most valid reason is that there is hardly any recycling firm for paper reuse in Oman, meanwhile a lot of commodities are being imported into Oman which brings along huge quantity of cardboards and packing paper products.

The third large category in the waste stream is plastic waste; the plastic waste is categorized further in this

study as follows. Plastic containers; 3.40% by weight and 17.46% by volume in winter and 6.40% by weight and 17.86% by volume in summer. Plastic bags; which accounts for 11.80% by weight and 16.88% by volume in winter and 6.60% by weight and 9.97% by volume in summer. Other plastics; this includes other than plastic containers and plastic bags; it is 1.20% by weight and 4.57% by volume in winter, and 3.60% by weight and 6.18% by volume in summer. Generally, the term “mixed plastic” is used for the mixture of all types of plastic found in MSW. All the three types of plastic waste together comes to 16.40% by weight and 38.91% by volume in winter and 16.60% by weight and 34.01% by volume in summer. Similar results were found in some of the Asian countries, for instance in Malaysia, the percentage weight of plastic waste is about 14, 11.8 in Singapore and 11% in Japan, 19% in Hong Kong and 19.72-22.79 % in Taiwan [3]. Results from this study shows that the percentage by volume is comparatively high, even though the percentage by weight is less, which means, the space going to be occupied by the plastic waste in landfill is relatively very high. It was observed in the study that plastic containers of soft drinks and beverages are found all over the waste piles in the landfill site. In Oman, milk and milk products like yogurt, leban, cheese, juices and soft drinks which are frequently consumed essential foods come in plastic containers itself contribute to larger composition in the waste stream. Plastic containers tend to occupy more space in landfill due to its rigidity against compaction in the landfill.

Next to plastic waste, the glass waste is 8% in winter and 8.60% in summer by weight. Glass waste includes beverage bottles, juice bottles and so on. The glass bottles were observed either unbroken or partially broken. The inert matter is about 6.96% by weight and 3.48% by volume in winter and summer; it mainly contains inseparable small sized materials like food particles, paper waste and other waste particles. This type of waste mainly arises from street sweepings and household. The samples also comprised of textiles and gunny bags to some extent. Textile and gunny bags have occupied 2.70% by weight and 5.38% by volume in both the seasons. This type of waste includes old and torn clothes and jute bags.

In general, findings of this study have similar results to those found in GCC, Arab and few Asian countries. The fractions of MSW in Kuwait, the organics and paper were reported to be 49% and 21%, respectively. Plastics, glass & metal, wood & fibres, and other miscellaneous types of MSW were reported as 13%, 6%, 10%, and 1%, respectively [18], [3]. Also it is evident that in countries with high per capita incomes, paper is the major component followed by organic matter and plastics; in the countries with middle and lower income, organic matter is the major component followed by paper and plastics [19], [3]. This is true also in the case of Oman where per capita income is similar to the middle income countries.

#### 4. Conclusion

The generation of municipal solid waste is increasing in Oman due to the increased population density, consumption pattern, life style behavior and economic development etc. Food waste (mixed), paper and cardboard waste and plastic waste are dominant in the waste stream. The waste stream has higher percentage of organic waste compared to the inorganic. The high amount of organic waste can be effectively used as organic manure through composting whereas recycling and energy recovery would be an appropriate option for the inorganic fraction of the waste stream.

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