



## SOLID WASTE GENERATION AND RATE COMPONENTS PERCENTAGE IN BAGHDAD CITY

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**Abstract:** A mixed methodological approach including field investigation, questionnaire survey, and structured and face-to-face interviews were employed in the gathering of data to obtain Municipal Solid Waste (MSW) generation rate and physical compositions data. Samples were taken from different neighborhoods through a two sampling periods in 1/ 8 / 2015 to 1/ 9 / 2015 and in 1 / 12 / 2015 to 1 / 1 / 2016. Based on the results of the preliminary survey for 99% confidence interval and 5% standard error, the optimum size, n, was 100. Stratified random sampling procedure was applied, in which sampling sites were allocated to high, middle and low-income socio-economic categories. The research concluded that average generation rates of: organic waste was 0.396 kg/capita.day, cellulosic waste was 0.072 kg/capita.day, and total waste was 0.673 kg/ capita.day.

**Keywords:** *Municipal Solid Waste (MSW), cellulosic, organic waste, generation rate,*

### معدل تولد النفايات الصلبة والنسب المئوية للمكونات في مدينة بغداد

**الخلاصة:** تم استخدام منهج متعدد لغرض جمع المعلومات الخاصة بتولد المخلفات الصلبة البلدية و تركيبها الفيزيائي متضمنة البحث المحلي ، والمسح الميداني ، وتوظيف المقابلات الشخصية ، و سحب عدد من النماذج من مناطق سكنية محددة ولفترتين مختلفتين فقد امتدت الفترة الاولى من ٢٠١٥/٨/١ لغاية ٢٠١٥/٩/١ في حين امتدت الفترة الثانية من ٢٠١٥/١٢/١ لغاية ٢٠١٥/١/١ وذلك لتقييم التنوع في تولد المخلفات الصلبة وتركيبها تبعا للفصول المختلفة في السنة الواحدة .تم اجراء مسح ميداني تمهيدي لعدد من المنازل السكنية وعلى مستوى ٩٩% ونسبة خطأ ٥% للنتيجة بعدد النماذج الواجب سحبها وبلغت ١٠٠ نموذج بالاعتماد على طريقة النمذجة العشوائية وتم تحديد النسب المئوية تبعا للمستويات المعيشية للمجتمع العراقي ( مستوى معيشي عالي ، مستوى معيشي متوسط ، مستوى معيشي واطيء)بلغ معدل تولد المخلفات العضوية 0.396 كغم /شخص . يوم والمخلفات السليلوزية 0.072 كغم /شخص . يوم والمجموع الكلي للمخلفات المتولده لكل شخص يوميا 0.673 كغم /شخص . يوم.

## 1. Introduction

The introduction Municipal solid waste (MSW) is waste collected by or on behalf of a local authority. It comprises mostly household waste and it may include some commercial and

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industrial wastes. Nationally, the quantity of MSW has risen year after year, presenting a growing problem for local authorities [1]. One of the guiding principles of European and UK waste management has been the concept of a hierarchy of waste management options, where the most desirable option is not to produce the waste in the first place (waste prevention) and the least desirable option is to dispose of the waste with no recovery of either materials and/or energy. Between these two extremes, there are a wide variety of waste treatment options that may be used as part of a waste management strategy to recover materials or to generate energy [2]. At present more than 88% of all MSW generated in Baghdad is disposed of in open dumps.

It includes paper, plastic, glass, metal cans, food scraps, and yard trimmings, keeping in mind that the greater proportion of these materials are degradable. However, Iraqi Ministry of Environment requires waste to be treated prior to disposal and has been trying to limit the amount of biodegradable municipal waste (BMW) that will be sent for disposal in landfills [3]. Thermal disposal methods like incineration, combustion, pyrolysis and gasification offer great benefits over traditional methods of disposing MSW. These thermal methods not only recover useful energy values from MSW but also reduce the quantity of waste being ultimately sent to landfills [4].

## **2. Experimental Work**

### ***2.1. The Local MSW Generation Rate and Composition for Food and Paper Waste***

Field work consisted of two stages. The first stage was to estimate local MSW generation rate and composition for food and cellulosic waste inclusively while the second stage was to incinerate separated cellulosic waste.

### ***2.2. MSW Sampling***

Baghdad governorate area covers about 5159 km<sup>2</sup>, where of 900 km<sup>2</sup> form the City of Baghdad, governed by the mayoralty. Five areas are located outside the city borders: Abu Ghraib, Mahmodya, Al-Madaen, Al-Tajee and Al-Rashdya. The Mayorality of Baghdad is divided into fourteen municipalities (Beladiya). The division of territories and names are listed in Table 1 [5]. A waste survey was conducted to obtain MSW generation rate and physical compositions data. The adopted test method was based on the American Society for Testing and Materials. This standard describes a test method for the determination of the mean composition of MSW based on collection and manual sorting of a number of samples of waste over a selected period. The waste survey was repeated two times in 1/ 8 / 2015 to 1/ 10 / 2015 and in 1 / 12 / 2015 to 1 / 1 / 2016 in order to assess the seasonal variation of the waste composition. Samples were taken from different neighborhoods through the two sampling periods and not focusing on waste coming from one district.

Table 1. Baghdad Districts [5].

| <i>Beladya Districts</i> |    |                        |
|--------------------------|----|------------------------|
| Rusafa                   | 1  | Al – Shaab             |
| East bank of Tigris      | 2  | Al – Ghadeer           |
|                          | 3  | New Baghdad (9 Nissan) |
|                          | 4  | Al – Sadder 1          |
|                          | 5  | Al - Sadder 2          |
|                          | 6  | Al – Adhamya           |
|                          | 7  | Al – Karada            |
|                          | 8  | Al – Rusafa            |
| Krakh                    | 9  | Al – Kadhmya           |
| West bank of Tigris      | 10 | Al – Karkh             |
|                          | 11 | Al – Dora              |
|                          | 12 | Al – Mansour           |
|                          | 13 | Al – Rasheed           |
|                          | 14 | Al – Shula             |

### 2.3. Survey Methodology

Before reporting of the weight of waste generated per capita is often confusing, as some figures include industrial waste, abandoned bulky, etc, while others may only report domestic and trade wastes. In order to avoid such confusion representative samples of the domestic waste were collected directly from household, weighed and analyzed at the end of each day work .The survey methodology adopted and presented in this research is in accordance with the recommendations of ASTM D-5231.3.2 [6].

### 2.4. Stratified Random Sampling

The method of proportional stratified random sampling was adopted,i.e. the total population was classified into groups (socio-economic level) and random samples were taken in each stratum in its proportion to the total population. In order to obtain reliable results, it was necessary to determine the minimum number of samples, which should be analyzed and evaluated to get data with reasonable accuracy. According to the sampling theory and the central limit theorem, the mean value a sample of (n) items drawn from population with a known mean (M) and standard deviation (SD) will also be (M) with an error, which is called the standard error[7]. Furthermore, the sample means are normally distributed as long as the sample is large enough ( $n > 30$ ) [6].The optimum sample size has been estimated by selecting a 99% confidence interval with an error of 5% of the mean value [7].As the standard deviation of the population is unknown, it is required to determine this parameter, and to do so it was necessary to run a preliminary survey.

## 2.5. Number of Samples

When Based on the results of the preliminary survey for 99% confidence interval and 5% standard error, the optimum sample size, n, was determined using "(1)" [7]:

$$n = [Z \times (SD)/R]^2 \quad (1)$$

Where:

n = minimum number of samples that will give the required precision;

z = score determined from statistical tables of the percentage for standard normal distribution;

SD = standard deviation of population which is equal to the standard deviation of the preliminary sample; and

R = standard error.

## 2.6. Population Percentages

After the required number of daily samples had been decided, the main sampling survey started. As the socio-economic level of population affects the quantities and the nature of the waste generated, a stratified random sampling procedure was applied, in which sampling sites were allocated to high, middle and low-income socio-economic categories. The socio-economic level of families who participated in the survey was determined based on household size, crowding, improved sanitation and type of roads to dwelling [8]. After selection of the sampling areas in Bagdad city in low, middle and high-income levels respectively, each householder was interviewed, to explain the purpose of the sampling project. Numbers of occupants were recorded in every dwelling and were supplied with plastic bags for manual sorting over the period of tests. Each full bag was labeled with its appropriate classification (H, M and L) referring to high, middle and low economic socio level.

The plastic bags of waste from nominated dwellings were collected, weighed individually to calculate food and paper solid waste generation rates in Baghdad City in kg/capita/day. Generation rates were obtained by utilizing "(2)" [9]:

$$CSWG = r_H \times SWGH + r_M \times SWGM + r_L \times SWGL \quad (2)$$

Where

CSWG: Composite Solid Waste Generation rate

r<sub>H</sub>: High-Income Society Ratio

SWGH: Solid Waste Generation Rate for High –Income Society

r<sub>M</sub>: Middle -Income Society Ratio

SWGM: Solid Waste Generation Rate for Middle –Income Society

r<sub>L</sub>: Low-income society ratio

SWGL: Solid Waste Generation Rate for Low –Income Society

Tools and equipment used in calculating food and paper waste generation rates are shown in Figure 1.



Figure 1. Tools and Equipment Used in Calculating Food and Paper Waste Generation Rates.

### 3. Results And Discussion

#### 3.1. Msw Generation Rate And Composition Of Food And Paper Waste

The preliminary sampling took place for 2 weeks (10/7/2015 to 23/7/2015) during which 280 samples were collected from 20 houses. The preliminary survey data were shown in Table.1 with the statistical analysis.

Table 1. Preliminary Sampling Survey

| <i>Residence no.</i> | <i>Total waste generated from residence(kg)</i> | <i>No. of capita per residence</i> | <i>Average generation rate (kg/capita/day)</i> |
|----------------------|---|------------------------------------|--|
| 1                    | 61.74   | 7                                  | 0.63   |
| 2                    | 47.04   | 8                                  | 0.42   |
| 3                    | 79.38   | 7                                  | 0.81   |
| 4                    | 42  | 6                                  | 0.50   |
| 5                    | 54.18   | 9                                  | 0.43   |
| 6                    | 27.72   | 6                                  | 0.33   |
| 7                    | 38.22   | 7                                  | 0.39   |
| 8                    | 39.2  | 7                                  | 0.40   |
| 9                    | 33.6  | 5                                  | 0.48   |
| 10                   | 59.36   | 8                                  | 0.53   |
| 11                   | 139.86  | 9                                  | 1.11   |
| 12                   | 31.5  | 5                                  | 0.45   |
| 13                   | 34.44   | 6                                  | 0.41   |
| 14                   | 32.48   | 4                                  | 0.58   |
| 15                   | 48.02   | 7                                  | 0.49   |
| 16                   | 32.9  | 5                                  | 0.47   |
| 17                   | 70.56   | 9                                  | 0.56   |
| 18                   | 97.02   | 9                                  | 0.77   |
| 19                   | 48.02   | 7                                  | 0.49   |
| 20                   | 36.4  | 5                                  | 0.52   |
| Total                | 1053.64   | 136                                | 10.77  |
| Average              | 52.682  | 6.8                                | 0.54   |
| SD.                  |   |                                    | 0.175  |

### 3.2. Number of Samples

The optimum sample size, or number of samples based on the results of the preliminary survey of  $SD = 0.175$  for 99% confidence interval, 5% standard error, and Z score of 2.58 was :

$$n = [2.58 \times (0.175)/0.05]^2$$

$$n = 82$$

One hundred samples were suggested to ensure high confidence, precision and overcome sampling errors.

### 3.3. Population Percentages

The total population of Baghdad studied at year 2014 by CSO will be adopted in this research. To ensure adequate and proper results, number of houses from each socio-economic category participating in the survey was proportional to their percentages in the community.

Information on the percentage of each socio-economic category in the community was not available [10].

Therefore, it was assumed according to districts as seen in Tables 2, 3, 4 and 5.

Table 2. No. of Population According to Districts of Baghdad [10].

| <i>District</i>  | <i>No. of population</i> | <i>% population</i> |
|------------------|--------------------------|---------------------|
| Center of rusafa | 1371598                  | 17.9                |
| Alwazeeriya      | 71365                    | 1                   |
| Zayona           | 164359                   | 2                   |
| Adhamiya         | 1234508                  | 16.1                |
| Sader 2          | 475041                   | 6.1                 |
| Sader1           | 668399                   | 8.8                 |
| Karkh            | 976663                   | 12.7                |
| Center of karkh  | 93455                    | 1.2                 |
| Alharthiya       | 55221                    | 0.8                 |
| Almansour        | 202391                   | 2.6                 |
| Yarmook          | 175981                   | 2.2                 |
| Kadhmiya         | 846379                   | 11                  |
| Mahmodiya        | 455803                   | 6                   |
| Abugareeb        | 304428                   | 4                   |
| Tarmiya          | 136645                   | 1.9                 |
| Madaen           | 433055                   | 5.7                 |
| Total            | 7665227                  | 100%                |

Numbers of samples for each socio-economic category are shown in Table 6.

Income measures are often used as an indicator of well-being. In Iraq due to price differences through different parts of the country, income is a less useful indicator of well-being.

Data on the level of income should be treated with caution, but the grouping of the population into levels according to the limitations listed above reveals that differences

in living conditions across Baghdad did not show significant differences in generation rates. Table 7 and 8 show solid waste generation rates in Baghdad according to levels in kg /capita.day for August /2015 and December / 2015 respectively

Table 3. Percentage of High Level Community in Baghdad [10].

| <i>District</i> | <i>No. of population</i> | <i>Percentage of total Baghdad population</i> |
|-----------------|--------------------------|---|
| Alwazeeriya     | 71365                    | 1   |
| Zayona          | 164359                   | 2   |
| Center of karkh | 93455                    | 1.2   |
| Alharthiya      | 55221                    | 0.8   |
| Almansour       | 202391                   | 2.6   |
| Yarmook         | 175981                   | 2.2   |
|                 | 762772                   | 9.9%  |

Table 4 Percentage of Middle Level Community in Baghdad [10].

| <i>District</i> | <i>No. of population</i> | <i>Percentage of total Baghdad population</i> |
|-----------------|--------------------------|---|
| Adhamiya        | 1234508                  | 16.1  |
| Karkh           | 976663                   | 12.7  |
| Kadhmiya        | 846379                   | 11  |
|                 | 3057550                  | 39.9%   |

Table 5. Percentage of Low Level Community in Baghdad [10].

| <i>District</i>  | <i>No. of population</i> | <i>Percentage of total Baghdad population</i> |
|------------------|--------------------------|---|
| Center of rusafa | 1371598                  | 17.9  |
| Sader 2          | 475041                   | 6.1   |
| Sader1           | 668399                   | 8.8   |
| Mahmodiya        | 455803                   | 6   |
| Abugareeb        | 304428                   | 4   |
| Tarmiya          | 136645                   | 1.9   |
| Madaen           | 433055                   | 5.7   |
| Total            | 3844969                  | 50.2%   |

Table 6. Number of Samples of Each Level for One Collection Period

| <i>Type of level of population</i> | <i>Percentage from total population</i> | <i>Number of samples of each levels for each collection period</i> |
|------------------------------------|---|--|
| High                               | 9.9 %                                   | 10   |
| Middle                             | 39.9 %                                  | 40   |
| Low                                | 50.2 %                                  | 50   |
| Total                              | 100%                                    | 100  |

Table 7. Rate of Organic Waste, Cellulosic Waste, and Remaining Waste as Kg / Capita.Day in Baghdad for August / 2015

| Type of level<br>(kg/capita.day) | The rate of<br>organic waste | The rate of<br>cellulosic waste | The rate of<br>remaining waste | The rate of total<br>waste generated |
|----------------------------------|------------------------------|---------------------------------|--------------------------------|--------------------------------------|
| High level                       | 0.39                         | 0.09                            | 0.25                           | 0.73                                 |
| Mid. Level                       | 0.40                         | 0.09                            | 0.21                           | 0.70                                 |
| Low level                        | 0.41                         | 0.08                            | 0.20                           | 0.69                                 |

Table 8. Rate of Organic Waste, Cellulosic Waste, and Remaining Waste as Kg / Capita .Day in Baghdad for December / 2015

| Type of level<br>(kg/capita.day) | The rate of<br>organic waste | The rate of<br>cellulosic waste | The rate of<br>remaining waste | The rate of total<br>waste |
|----------------------------------|------------------------------|---------------------------------|--------------------------------|----------------------------|
| High level                       | 0.38                         | 0.06                            | 0.24                           | 0.68                       |
| Mid. Level                       | .39                          | 0.07                            | 0.21                           | 0.67                       |
| Low level                        | 0.39                         | 0.05                            | 0.19                           | 0.63                       |

Generation rates were obtained by utilizing "(2)" Calculations are shown in Table 9 and 10.

As it can be seen, generation rates of solid waste in this study for high, middle and low income levels got almost the same figures.

Spot or inadequate samples maybe entirely misleading, besides there were considerable problems involved in obtaining a representative sample of different levels due to intrusions of different socio-levels. Yet the reason for measuring generation rates is to obtain data that can be used to determine the total amount of wastes to be measured.

Table 9. Rate of (Organic Waste, Cellulosic Waste, and Remaining Waste as Kg / Capita.Day in Baghdad August / 2015.

| August (kg/capita.day)   |  |
|--------------------------|--|
| Rate of organic waste    | $0.39 \times 10\% + 0.40 \times 40\% + 0.41 \times 50\% = 0.404$ |
| Rate of cellulosic waste | $0.09 \times 10\% + 0.09 \times 40\% + 0.08 \times 50\% = 0.085$ |
| Rate of remaining waste  | $0.25 \times 10\% + 0.21 \times 40\% + 0.20 \times 50\% = 0.209$ |
| Rate of total waste      | $0.73 \times 10\% + 0.70 \times 40\% + 0.69 \times 50\% = 0.698$ |

Table 10. Rate of (Organic Waste, Cellulosic Waste, and Remaining Waste as Kg/Capita.Day in Baghdad December / 2015.

| December (kg/capita.day) |  |
|--------------------------|--|
| Rate of organic waste    | $0.38 \times 10\% + 0.39 \times 40\% + 0.39 \times 50\% = 0.389$ |
| Rate of cellulosic waste | $0.06 \times 10\% + 0.07 \times 40\% + 0.05 \times 50\% = 0.059$ |
| Rate of remaining waste  | $0.24 \times 10\% + 0.21 \times 40\% + 0.19 \times 50\% = 0.203$ |
| Rate of total waste      | $0.69 \times 10\% + 0.66 \times 40\% + 0.63 \times 50\% = 0.657$ |

Average data were summarized in Table 11.



Table 11. Average of Solid Waste Generation Rates in Baghdad City.

| <i>kg /capita.day</i>    | <i>August</i> | <i>December</i> | <i>average</i> |
|--------------------------|---------------|-----------------|----------------|
| Rate of organic waste    | ٠,٤٠٤         | ٠,٣٨٩           | 0.396          |
| Rate of cellulosic waste | ٠,٠٨٥         | ٠,٠٥٩           | 0.072          |
| Rate of remaining waste  | ٠,٢٠٩         | ٠,٢٠٣           | ٠,٢٠٦          |
| Rate of total waste      | ٠,٦٩٨         | ٠,٦٤٨           | 0.673          |

Different generation rates were obtained through studies carried out in some Iraqi governorates at different times of the year.

It was 0.35 kg/capita.day for Fallujah city [11], 0.420 kg/capita.day for Al-Najaf [12] and 0.7 kg/capita.day for Baghdad [13].

Table 12 shows a clear comparison for solid waste generation rates throughout some Iraqi governorates.

Total amount of solid waste generated in Baghdad in ton /day was calculated by multiplying generation rate in (kg/capita/day) by Baghdad population (capita) as shown in Table 13.

Table 12. Solid Waste Generation Rates in Some Iraqi Governorates.

| <i>City or governorates</i> | <i>Generation rates<br/>kg/capita/d</i> | <i>References</i> |
|-----------------------------|---|-------------------|
| Al-Mussel                   | 0.54                                    | [14]              |
| Kirkuk                      | 0.44                                    | [15]              |
| Al-Fallujah                 | 0.32                                    | [11]              |
| Al-Najaf                    | 0.42                                    | [12]              |
| Baghdad                     | 0.7                                     | [9]               |
| Baghdad                     | 1.20-1.4                                | [16]              |
| Baghdad                     | 0.63                                    | [13]              |
| Wassit                      | 0.53                                    | [17]              |
| Al-Ammarah                  | 0.60                                    | [1]               |

Table 13. Total Amount of MSW Generated in Baghdad in One Day.

| <i>Waste type</i> | <i>Generation rate<br/>(kg/capita.day)</i> | <i>Total weight in one<br/>day in Baghdad<br/>(ton /day)*</i> |
|-------------------|--|---|
| Food waste        | 0.396                                      | ٣٠٣٥,٤  |
| Cellulosic waste  | 0.072                                      | ٥٥١,٠   |
| Remaining waste   | ٠,٢٠٦                                      | ١٥٧٩,٠  |
| Total waste       | 0.673                                      | ٥١٥٨,٠  |

\* Generation rate x Baghdad total population

There are two components of MSW evaluated in this survey namely food and paper. As it can be noticed food waste is the major constituent of the residential solid waste .Yet the most important reason for high food waste is the absence of recycling programs. People are still not much aware of the environmental problems and safe disposal of the waste. They still have the feeling of NIMBY, where most of the city

people do not know where the collected waste is disposed. People are conscious regarding the waste problem within their compound but they do not care where and how the waste is disposed, and even if they know about the disposal place of the collected waste, they do not know whether the disposal practice is environmentally safe or not.

#### 4. Conclusions

The average generation rates of: organic waste was 0.396 kg/capita.day, cellulosic waste was 0.072 kg/capita.day, and total waste was 0.673 kg/capita.day, in Baghdad.

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