Chemical, Petroleum and Environmental Engineering

Babylon Governorate Municipal Solid Waste Generation Rate

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ABSTRACT

Municipal solid waste generation in Babylon Governorate is often affected by changes in lifestyles, population growth, social and cultural habits and improved economic conditions. This effect will make it difficult to plan and draw up future plans for solid waste management.

In this study, municipal solid waste was divided into residential and commercial solid wastes. Residential solid wastes were represented by household wastes, while commercial solid wastes included commercial, institutional and municipal services wastes.

For residential solid wastes, the relational stratified random sampling was implemented, that is the total population should be divided into clusters (socio-income level), a random sample was taken in each level in its proportion to the total population. According to the obtained results of the primary survey of 5% standard error and 99% confidence interval, held in Babylon Governorate, the best sample size was 44. Samples were taken as a daily collection for 10 days, this process was repeated for four different periods to cover the change in the waste generation between summer and winter season. The study showed that Babylon Governorate has an average residential solid wastes generation rate of 0.587 kg per capita per day.

If the quantities of commercial solid waste were to be added; solid waste generation rate reaches 0.802 kg per capita per day as a 36.6 % increase. The research adopts the value of 0.802 kg/capita. day as a waste generation rate for Babylon Governorate.

Keywords: Municipal solid waste (MSW), socio-income level, generation rate, Babylon Governorate.

معدل تولد النفايات الصلبة البلدية في محافظة بابل

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الخلاصة

يتأثر توليد النفايات الصلبة البلدية في محافظة بابل بالنمو السكاني والتحضر والظروف الاقتصادية والتغيرات في أنماط الحياة والعادات الاجتماعية والثقافية. وهذا التأثير سيؤدي الى صعوبة في عملية التخطيط ورسم الخطط المستقبلية في ادارة النفايات الصلبة.

في هذه الدراسة، تم تقسيم النفايات الصلبة البلدية إلى النفايات الصلبة السكنية والتجارية. وتمثل النفايات المنزلية الصلبة النفايات المنزلية، بينما تشمل النفايات التجارية الصلبة نفايات الخدمات التجارية والمؤسسية والبلدية.

وفيما يتعلق بالنفايات الصلبة السكنية، اعتمدت العينة العشوائية النسبية في عملية مسح العينات، أي أن مجموع السكان مقسم إلى مجموعات حسب مستويات الدخل الاجتماعي، وأخذت عينات عشوائية في كل مستوى من حيث نسبتها إلى مجموع السكان. واستنادا إلى نتائج المسح الأولي لدرجة ثقة 99٪ و5٪ خطأ قياسي، الذي عقد في محافظة بابل، تبين أن عدد العينات المثلى هو 44. تم أخذت العينات بشكل جمع يومي لمدة 10 ايام، وتكررت هذه العملية لأربع فترات مختلفة لتغطية التغير في توليد النفايات بين فصل الصيف والشتاء. وأظهرت الدراسة أن متوسط معدل إنتاج النفايات المنزلية الصلبة في مدينة بابل يبلغ 0.587 كغم للفرد في اليوم. ولا تشمل هذه الكمية النفايات التجارية المتولدة في محافظة بابل، إذا أضيفت هذه الكميات، فإن معدل إنتاج النفايات الصلبة يصل إلى 0.802 كيلوغرام للفرد في اليوم الواحد بنسبة زيادة 36.6٪ من النفايات الصلبة المنزلية المتولدة.

الكلمات الرئيسية: النفايات الصلبة البلدية، مستوى الدخل الاجتماعي، معدل التولد، محافظة بابل.

1. INTRODUCTION

Uncontrolled growth rates and fast urbanization of population hasten the generation of municipal solid waste (MSW). Socio-economic profile of the population, increasing population density, industrialization, and depletion pattern govern the features and quantity of MSW generated **Tchobanoglous, et al., 1993**.

Major sources of MSW in the metropolitan area are residential areas, commercial or market areas, offices, and institutions. The percent distribution of solid waste from various sources are different, such as municipal solid waste generating from commercial and market areas around 36.37%, household waste generating around 34.20%, street sweeping 22.80% and institutions around 6.32% of MSW, **Das and Bhattacharyya, 2014.**

MSW is a heterogeneous material due to widely varying sizes and shapes and composition. The production rates and composition vary from place to place and from season to season. Most previous studies evaluate the quantity of MSW at transfer stations and landfills sites **Jasim, 2012 and Thameer, 2016**, but authors such as **AbuQdais, et al., 1997, Al-Ameen and Graimed, 2010 and Hussein, 2016,** decided to conduct the survey at the source of generation giving the following reasons:

- Climatic conditions affect solid waste properties during storage, collection and transportation processes. Results based on sampling at transfer stations or landfill sites, which are supposed to reflect the actual characteristics of the wastes, will not be reliable, while sampling at the point of generation will produce more accurate data.
- In order to assess the effect of the socio-economic level of householders on MSW quantities and composition, it is important to know the source of the sampled waste and this will be an impossible task as sampling takes place at the transfer station or landfill site where waste was mixed coming from different homes having different socio-economic levels.

Due to the heterogeneity, variability, climatic conditions affect and socio-economic level, it is necessary to carry out a statistically designed sampling survey by which the average quantities and composition of waste can be accurately estimated. From a statistical point of view, the accuracy of determination of these parameters will be increased by increasing the number of samples which will be analyzed **Owen and Jones, 1994**.

On the other hand, economy and limited resources dictate that the number of samples should be as minimum as possible. To meet both statistical and economic requirements, the number of samples is usually determined by first selecting the required accuracy **ASTM D5231-92, 2003**.

For example, **AbuQdais, et al., 1997,** found that 40 samples were required to give a 95% confidence interval with 10% standard error. **Al-Ameen and Graimed, 2010,** with a confidence interval of 99% and standard error of 10% in Al-Ammarah City, found that the optimum sample size was shown to be 104. **Hussein, 2016,** for 99% confidence interval and 5% standard error, found that the optimum sample size was 100.

Household wastes constitute the largest percentage of MSW for this reason the unit of kilograms per capita per day is adopted. The unit of measure is easily applicable for household wastes where the per capita value can be directly multiplied by the population to obtain the total amount. In the case of the other MSW types such as a hospital (non-hazardous), commercial, municipal services, and institution solid waste, the relation is not direct. These wastes are usually expressed as a percentage of the production **International Bank of Reconstruction and Development (IBRD), 1999**.

Waste generation rates are closely related to the economic prosperity. Typically, low-income countries have the lowest percentage of urban populations and the lowest waste generation rates, ranging from 0.10 to 0.50 kg per capita per day. As income level increases toward the middle-income range, the per capita urban waste generation rates also increase, ranging from 0.50 to 1.10 kg per capita per day. As predicted, the high-income countries show the greatest urban waste generation rates, typically above 1.10 kg per capita per day **Khajuria, et al., 2010**.

According to **Alsamawi, et al., 2009,** Iraq is classified as middle-income countries having 0.63 kg per capita per day as a solid waste generation rate. Babylon Municipalities adopts 1.0 kg per capita per day of MSW as a generation rate of residential and commercial solid wastes as a rough estimate for ease and speed of performance **Iraqi Ministry of Municipalities and Public Works, 2017**.

The present paper attempts to conduct the survey at the source of wastes generation and calculate the actual value of MSW generated as well as obtain the missing percentage of commercial solid wastes, in Babylon Governorate.

2. EXPERIMENTAL WORK

Before any planning, collection, disposal, and development of MSW, the amount and volume of solid waste generated should be known to facilitate planning and making the right decision for future plans. In this study, MSW was divided into residential and commercial solid wastes. Residential solid wastes were represented by household wastes while commercial solid wastes included commercial, institutional and municipal services wastes.

2.1 Residential Solid Wastes

A waste survey was conducted to obtain residential solid wastes generation rate. 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 amount of residential solid wastes based on a collection of a number of samples of waste over a selected period **ASTM D5231-92, 2003**.

The survey was repeated four times in different months (September 2016, December 2016, March 2017 and June 2017) to cover the change in amount of waste during the year seasons as well as to compare the calculated generation rate with the estimated generation rate achieved by Babylon Municipalities to figure out the amount of commercial waste.

2.2 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 **Owen and Jones, 1994**. 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 of a sample of (N) items drawn from a population with a known mean (M) and standard deviation (SD) will also be (M) with an error, which is called the standard error. Furthermore, the sample means are normally distributed as long as the sample is large enough (N > 30) **Owen and Jones, 1994**.

The optimum sample size has been estimated by selecting a 99 % confidence interval with a standard error of 5 % of the mean value. As the standard deviation of the population is unknown, it is required to determine this parameter, through a preliminary survey.

2.3 Number of Samples

Based on the results of the preliminary survey for 99.0 % confidence interval and 5.0 % standard error, the optimum sample size is N, by using **Eq.1, ASTM D5231-92, 2003**:

$$N = \left(\frac{Z \times SD}{R}\right)^2 \tag{1}$$

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 the population which is equal to the standard deviation of the preliminary sample; and
    R = sampling error.

2.4 Income Level and Sample Selection

As the required number of daily samples had been decided, the main sampling survey started, and since the socio-economic level of a 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 levels of families who participated in the survey was based on the information provided by Real Estate Registration Department of Babylon regarding luxurious areas of each district and household size as well as the estimates of the property price for each area of the province (data not shown). **Table 1** shows the information obtained regarding population classification in all Babylon districts **Iraqi Ministry of Justice, 2016**.

As sampling areas in Babylon Governorate were allocated in low, middle and high-income levels, each house owner 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 waste collection 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 were nominated according to dwellings, weighed individually to calculate solid waste generation rates in Babylon in kg/capita.day.

Generation rates of residential solid wastes were obtained by utilizing **Eq. 2, Tchobanoglous, 2001:**

$$CSWG = rH \times SWGH + rM \times SWGM + rL \times SWGL \qquad (2)$$

where:

CSWG: Composite solid waste generation rate;

rH: High- income society ratio;

SWGH: Solid waste generation rate for High- income society;

rM: Middle-income society ratio;

SWGM: Solid waste generation rate for Middle-income society;

rL: Low-income society ratio; and

SWGL: Solid waste generation rate for Low-income society.

2.5 Commercial Solid Wastes

A comparison was made between the collected wastes by municipal server and field survey of samples in the residential area in the same period of time to find the percentage of commercial solid wastes.

The amount of solid waste collected by collection municipal vehicles was estimated by calculating a number of collection vehicles entering landfill sites during months of (September 2016, December 2016, March 2017 and June 2017) and multiplying by vehicles capacity, assuming an 85% of its total capacity.

To find the percentage of commercial solid wastes, **Eq. 3** was used:

$$\% \ CSW \ = \frac{WCV - RWG}{WCV} \times 100\% \qquad (3)$$

Where:

% CSW: Percentage of commercial solid wastes;

WCV: Solid waste generation rate according to municipal vehicles (Kg/capita. day); and,

RWG: Solid waste generation for the residential area (Kg/capita.day).

3. RESULTS AND DISCUSSION

3.1 MSW Generation Rate

A preliminary sampling took place for 10 days (10/ 8/ 2016 to 20/ 8 / 2016) during which 200 samples were collected from 20 houses and different districts. The preliminary survey data were shown in **Table 2** with statistical analysis.

3.2 Number of Samples

The optimum sample size, or number of samples based on the results of the preliminary survey having SD = 0.129 for 99.0 % confidence interval, 5.0 % standard error and Z score of 2.575 was:

$$N = [Z \ x \ (SD)/R]^2 = ((2.575x \ 0.129)/0.05)^2 = 44.136 \ samples$$

Fifty samples a day were suggested to ensure high confidence, precision and overcome sampling errors.

3.3 Population Percentages

To ensure adequate and proper results, the districts and neighborhoods were classified according to the socio-economic level as shown in **Table 1**. Unit generation rates can be determined by using field data collected from a representative sample.

To find the ratio of each socio-economic level, each number will be divided by the total population, where high-income represents 10.5 %, middle-income 41.3 % and low-income 48.2 % of the total population as illustrated in **Fig.1**.

Based on these percentages, 5 high incomes, 21 middle income, and 24 samples of low income were collected daily making 50 total samples.

3.4 Sampling Survey

The main sampling survey started with the above-mentioned classification of samples. The sampling sites which were involved is illustrated in **Fig. 3**.

Plastic bags were distributed to the selected residence to collect solid wastes. 2,000 samples were collected in four seasons for 10 days of daily collection from 50 houses.

The average generation rates of residential solid waste for different economic levels are as listed in **Table 3**.

As generation rates of solid waste for high, middle and low-income levels are nearly close to each other; this may be attributed to many considerable problems involved in obtaining a representative sample of different levels due to intrusions of different socio-levels.

However, there is a significant difference between high and low-income levels, this might be attributed to that, although food waste represents the highest percentages in the waste stream, most local residents in low-income level keep on giving their food wastes to their animals as soon as generated and thus were not encountered in calculations. It is important to have the waste generation information and amounts collected, as these data will have a major impact on the planning process.

Depending on the results from **Fig. 1** and **Table 3**, the weighted average generation rate for residential solid wastes in Babylon Governorate can be determined using **Eq. 2** to be 0.587 kg/ capita.day as shown in **Table 4**.

3.5 Commercial Solid Wastes

The amount of MSW collected by the Babylon Municipalities are estimated value and do not represent the total governorate population, in fact only urban population. Therefore, they were used only to obtain the missing percentage of commercial solid wastes.

Many kinds of literature adopted a percentage of commercial solid wastes as a value of 30 to 45 % of total MSW generated as a rough estimate. In this study, the actual comparison was made between the wastes collected by municipality team and field sampling survey to find the true percentage of commercial solid waste generated.

The percentage of commercial solid wastes was found by applying **Eq. 3**. The result is shown in **Table 5.**

The actual MSW generation rate in Babylon Governorate was calculated by multiplying the average residential wastes generation (RWG) 0.587 kilograms per capita per day by the percentage of commercial solid wastes (% CSW) 36.6 % to be 0.802 kilograms per capita per day for the year 2017.

With 2,121,889 population size in year 2017, daily waste generated is about 1,702 tons/day that is a 621,141 tons / year.

Different generation rates were obtained through studies carried out in different Iraqi governorates at different times of the year. **Table 6** shows a clear comparison for MSW generation rates throughout different Iraqi governorates.

Most data indicate a general increase in waste generation trends as the socio-economic levels of the population being served increase, yet increment may be accompanied or followed by a slight reduction, or at least a slow increment based on legislation and waste reduction policies implemented from time to time.

4. CONCLUSIONS

This survey showed an average residential solid waste generation rate of 0.587 kg per capita per day, with an increase of about 36.6% for commercial solid wastes. The overall MSW generation rate was calculated to be 0.802 kg per capita per day for Babylon Governorate.

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NOMENCLATURE

MSW = municipal solid waste, (kg/capita.day).
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 the population.
R = sampling error.
CSWG = composite solid waste generation rate.
rH = high- income society ratio.
SWGH = solid waste generation rate for high- income society.
rM = middle-income society ratio.
SWGM = solid waste generation rate for middle-income society.
rL = Low-income society ratio.
SWGL = solid waste generation rate for low-income society.
CSW = percentage of commercial solid wastes.
WCV = solid waste generation rate according to municipal vehicles, (kg/capita. day).
RWG = solid waste generation for residential area, (kg/capita.day).

Table 1. Classification of the population by socio-economic level in Babylon Governorate,
Iraqi Ministry of Justice, 2016.

I	Districts	Total population (2017)	High income	Middle income	Low income
1	Al-Hilla district	595,980	137,075	339,709	119,196
2	Al-Kifil	150,657	7,985	45,197	97,475
3	Abo Gharaq	116,623	9,097	43,151	64,376
4	Al-Mahaweel district	125,445	10,663	51,432	63,350
5	Al-Mashru'	136,579	3,551	39,608	93,420
6	Al-Imam	39,541	1,344	14,235	23,962
7	Al-Nile	63,256	1,708	20,242	41,306
8	Al-Hashimiya district	38,069	4,492	14,847	18,730
9	Al-Qasem	170,466	16,365	73,300	80,801
10	Al-Madhatiya	145,517	2,183	45,110	98,224

11	Al-Shumaly	93,669	2,248	30,911	60,510
12	Al-Tali'a	41,815	1,338	11,708	28,768
13	Al-Mussayab district	124,109	14,024	53,367	56,718
14	Sadt Alhindiya	96,509	5,984	31,848	58,677
15	Jurf Alnasr	32,012	256	8,643	23,113
16	Al-Iskandariy	151,642	4,246	53,075	94,321
	Total	**2,121,889**	**222,559**	**876,383**	**1,022,947**

Table 2. Preliminary sampling survey.

Sample NO.	Total Waste Generated from Residence (kg)	No. of Capita per Residence	Average Generation Rate (kg/capita.day)
S1	32.324	7	0.462
S2	17.394	3	0.580
S3	26.810	6	0.447
S4	33.109	8	0.414
S5	31.640	4	0.791
S6	46.548	9	0.517
S7	8.567	2	0.428
S8	39.620	7	0.566
S9	26.342	5	0.527
S10	31.770	8	0.397
S11	73.467	10	0.735
S12	14.460	3	0.482
S13	31.555	5	0.631
S14	55.785	8	0.697

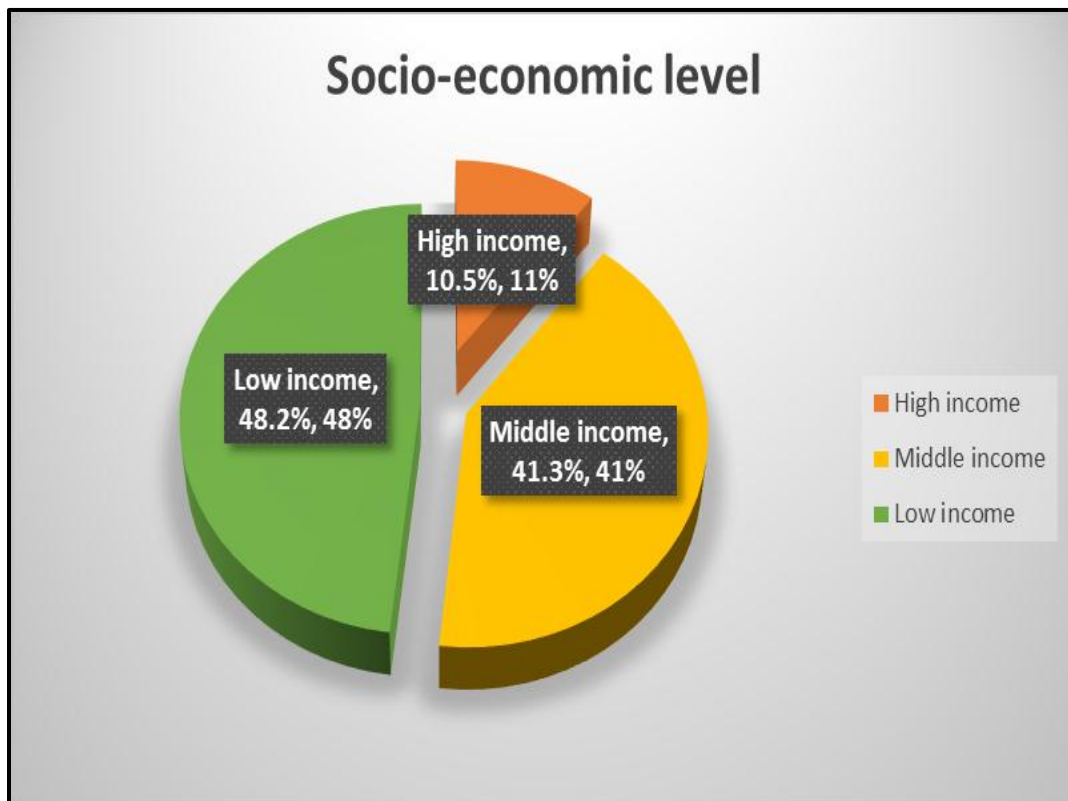|			
S15	50.263	7	0.718
S16	10.178	2	0.509
S17	40.070	5	0.801
S18	19.011	4	0.475
S19	61.498	9	0.683
S20	39.779	8	0.497
Average Generation Rate (kg/capita.day)			**0.568**
Standard Deviation (S.D)			**0.129**

Figure 1. Socio-levels percentage in Babylon Governorate **Iraqi Ministry of Justice, 2016**.
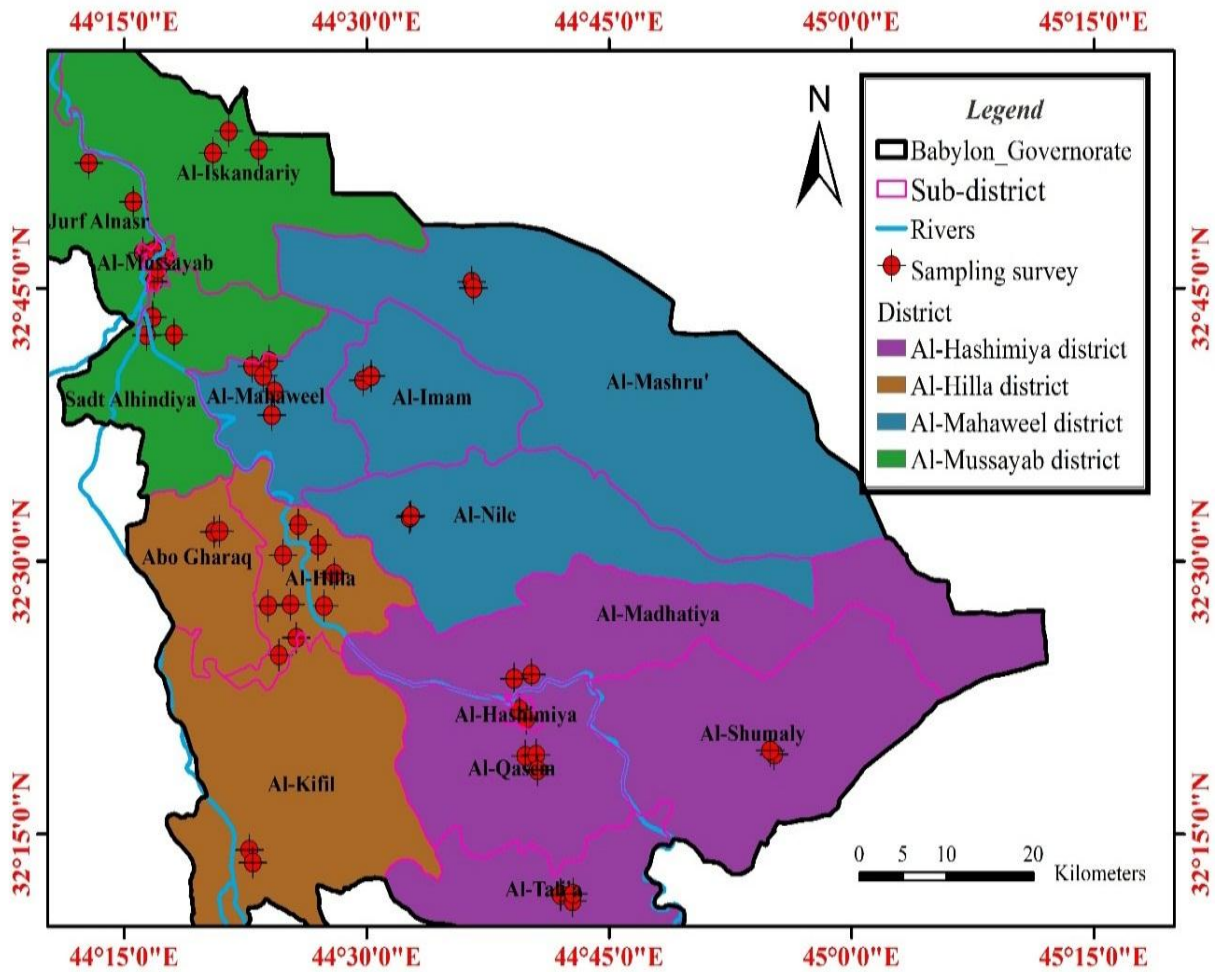
Figure 2. Sampling Sites.

Table 3. Generation rates of residential solid wastes with different income levels.

I	Months	High-income (kg/capita.day)	Middle-income (kg/capita.day)	Low-income (kg/capita.day)
1	Sep-16	0.697	0.685	0.500
2	Dec-16	0.594	0.597	0.404
3	Mar-17	0.654	0.642	0.450
4	Jun-17	0.831	0.770	0.605
Average		**0.694**	**0.673**	**0.490**

Table 4. Weighted average generation rate for residential solid wastes in Babylon Governorate.

I	Months	CSWG = rH × SWGH + rM × SWGM + rL × SWGL	Average generation rate (kg/capita.day)
1	Sep-16	0.697 x 10.5% +0.685 x 41.3% +0.500 x 48.2%	0.597
2	Dec-16	0.594 x 10.5% +0.597 x 41.3% +0.404 x 48.2%	0.504
3	Mar-17	0.654 x 10.5% +0.642 x 41.3% +0.450 x 48.2%	0.551
4	Jun-17	0.831 x 10.5% +0.770 x 41.3% +0.605 x 48.2%	0.697
Average generation rate for residential solid waste (kg/capita.day)			**0.587**

Table 5. Percentage of commercial solid waste.

I	Months	RWG (kg/capita.day)	WCV (kg/capita.day)	% CSW
1	Sep-16	0.597	0.913	34.6
2	Dec-16	0.504	0.821	38.7
3	Mar-17	0.551	0.862	36.1
4	Jun-17	0.697	1.108	37.1
Average		**0.587**	**0.926**	**36.6**

Table 6. MSW generation rates in different Iraqi Governorates.

I	City or Governorates	Generation rates (kg/capita.day)	References
1	Fallujah City	0.35	**Al-Jumaily, 1998**
2	Al-Mussel	0.54	**Fwezi, 1998**
3	Kirkuk	0.44	**Al-Najar, 1998**
4	Al-Najaf	0.42	**Hamoud, 2005**
5	Baghdad	0.7	**Al-Nakeeb, 2007**
6	Al-Kut	0.53	**Graimed, 2009**
7	AL-Ammarah City	0.66	**Al-Ameen and Graimed, 2010**
8	Baghdad	0.673	**Hussein, 2016**
9	Basrah	0.62	**Abbas et al., 2016**