

Estimation of Domestic Solid Waste Amount and Its Required Landfill Volume in Najaf Governorate-Iraq for the Period 2015-2035

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Abstract

Solid waste management is one of the most important challenges facing the local administration in the governorate of Najaf. This paper investigates the domestic amount generated in Najaf governorate for period 2015-2035 and the required landfill volume for the disposal of the waste. The daily per capita waste generation in Al-Najaf is 0.42 kg, the humidity content about 43% and the density of waste around 473 kg/m³. The total amount was about 5,914,415 ton and the required landfill volume is 11,828,829 m³.

Keywords

Najaf Governorate, Iraq, Domestic Solid Waste, Landfill

1. Introduction

In the 20th century, due to industrial revolution and technology development, consumption patterns of the people all over the globe have changed and the use of natural resources and goods has increased manifold. Due to this, huge quantities of different types of solid wastes are produced every day creating an alarming problem of their disposal.

In Iraq, after decades of turmoil and international sanctions many of the key infrastructures within Iraq have fallen into disrepair, leading to a terminal decline in the provision of basic and essential services. This is particularly true of waste and resource management which has seen years of underdevelopment and deterioration. This has resulted in a lack of provision of basic public services in the waste sector which have been replaced by a burgeoning black market in waste collection, disposal and recycling [1].

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In Najaf governorate (**Figure 1**), solid waste management aspect is regarded as one of the major challenges faced by the local administration. This issue is one of the reasons of the political conflict in the governorate because of the saintliness of the city and the increasing in solid waste generation.

Generation rate in Iraq is between (0.35 - 0.65 kg/capita. day) as middle-income country [2]. This rate varies from place to place where it reaches (0.42 kg/capita. day) in Najaf governorate [3], (0.44 kg/capita. day) in Kirkuk city [4] and (0.496 kg/capita. day) in Mousel city [5].

The main aims of this study are to:

- 1) Estimate the amount of domestic solid waste to be generated during period 2015-2035 for future planning for solid waste management and land in Najaf governorate.
- 2) Calculate the required landfills volume for the disposal of this amount in a safety way without any environment risks.

2. Study Area

The study area hosts the shrine of Ali Ibn Abi Talib, making it a holy place for both Shia and Sunni Muslims. Wadi Al-Salam (valley of peace) is also located in this governorate which is an important Shia burial ground and it is a prominent center of Shia learning. Najaf governorate lies between coordinates latitudes (32°21'N and 29°50'N), longitudes (44°44'E and 42°50'E) with total area 28,824 sq. km (6.6% of Iraq). Administratively, Al-Najaf governorate includes three qadhaas (Administrative units comprising the Governorate) (Al-Manathera, Al-Kufa and Al-Najaf Qadhaa) (**Figure 1**).

Based in data from [6], the population and growth rate for the study area is as shown in **Table 1**.

3. Calculation of Domestic Solid Waste Volume

Domestic solid waste (domestic waste and portion of commercial waste (visitors waste) were calculated as

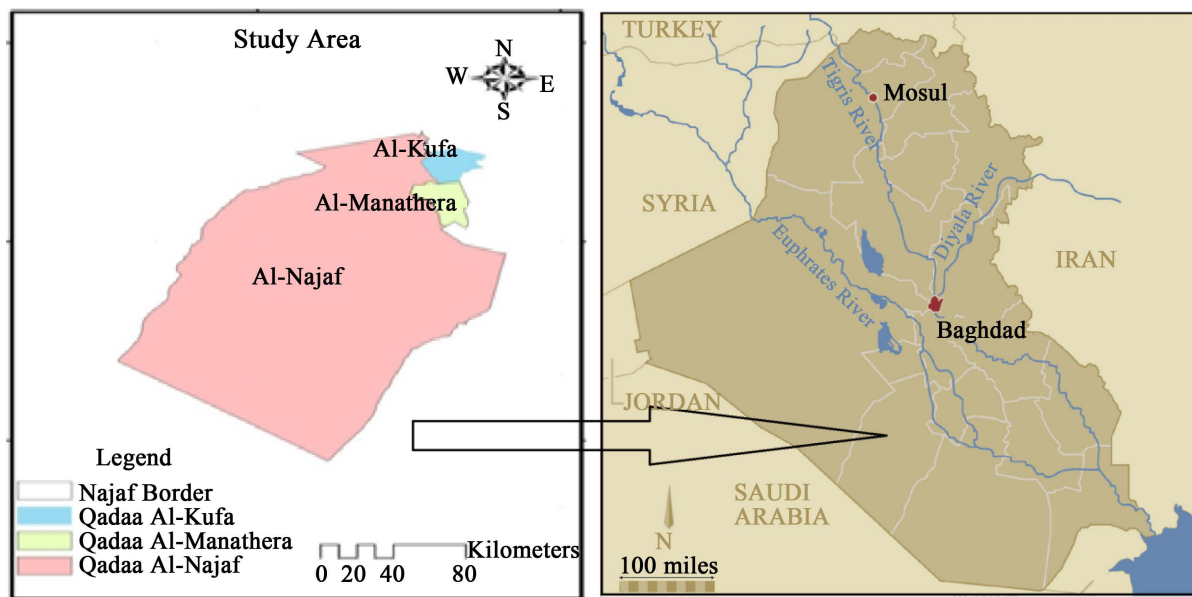


Figure 1. Map of study area.

Table 1. Population and growth rate for each Qadhaa.

| Qadhaa | 2014 Population | Growth rate% |
|-----------|-----------------|--------------|
| Najaf | 786,804 | 2.7 |
| Kufa | 346,145 | 2.5 |
| Manathera | 256,599 | 2.3 |

well as the approximate amount to be generated in the coming 20 years (2015-2035). This information was used to find out the required landfill volume based on the following steps.

3.1. 1-Estimation the Population for Each Qadhaa

Population for each Qadhaa for period study (2015-2035) was estimated based the flowing equation [7]:

$$P_i = P_o (1 + r)^n$$

P_i = population in target year

P_o = population in base year

n = number of years.

r = Growth rate.

For each Qadhaa, the growth rate used was for Al-Najaf, Al-Kufa and Al-Manathera Qadhaa is 2.7%, 2.5%, 2.3% [6].

3.2. Calculating the Amount of Domestic Solid Waste for Period from 2015 to 2035

Based on population estimated from previous equation and domestic and visitors waste generation rate (0.42 kg/capita. day and 0.23 kg/capita day) respectively [2] [3] the Amount of domestic waste for period from 2015 to 2035 for each Qadhaa is:

1) Al-Najaf Qadhaa

Based on the population in 2015 and 2016 and the growth rate (Table 1); 1,485,000 individuals visit Al-Najaf Qadhaa each year. These visitors generate waste 0.23 kg/capita. day. The generated waste rate for the visitors, the population and solid waste amount for Najaf Qadhaa for the period (2015-2035) is show in Table 2 and Figure 2.

Table 2. Solid waste in Al-Najaf Qadhaa and its population.

| Year | Population | Visitors [10] | Total Solid waste(ton) |
|------|------------|---------------|------------------------|
| 2015 | 808,048 | 1,485,000 | *122,518 |
| 2016 | 829,865 | 1,485,000 | 125,817 |
| 2017 | 852,271 | 1,485,000 | 129,205 |
| 2018 | 875,283 | 1,485,000 | 132,684 |
| 2019 | 898,915 | 1,485,000 | 136,258 |
| 2020 | 923,186 | 1,485,000 | 139,927 |
| 2021 | 948,112 | 1,485,000 | 143,696 |
| 2022 | 973,711 | 1,485,000 | 147,567 |
| 2023 | 1,000,001 | 1,485,000 | 151,542 |
| 2024 | 1,027,001 | 1,485,000 | 155,624 |
| 2025 | 1,054,730 | 1,485,000 | 159,817 |
| 2026 | 1,083,208 | 1,485,000 | 164,123 |
| 2027 | 1,112,455 | 1,485,000 | 168,545 |
| 2028 | 1,142,491 | 1,485,000 | 173,086 |
| 2029 | 1,173,338 | 1,485,000 | 177,750 |
| 2030 | 1,205,018 | 1,485,000 | 182,540 |
| 2031 | 1,237,554 | 1,485,000 | 187,460 |
| 2032 | 1,270,968 | 1,485,000 | 192,512 |
| 2033 | 1,305,284 | 1,485,000 | 197,700 |
| 2034 | 1,340,527 | 1,485,000 | 203,029 |
| 2035 | 1,376,721 | 1,485,000 | 208,502 |
| SUM | | | 3,399,902 |

* = $((808,048 \times 0.42 \times 360) + 1,485,000 \times 0.23)/1000$.

2) Al-Kufa Qadhaa

Amount solid waste based on the population and growth rate (**Table 1**) for Al-Kufa Qadhaa for the period (2015-2035) was calculated as shown in **Table 3** and **Figure 3**.

Table 3. Population and solid waste in Al-Kufa Qadhaa.

| Year | Population | Solid waste(ton) |
|------|------------|------------------|
| 2015 | 354,799 | *53,646 |
| 2016 | 363,669 | 54,987 |
| 2017 | 372,760 | 56,361 |
| 2018 | 382,079 | 57,770 |
| 2019 | 391,631 | 59,215 |
| 2020 | 401,422 | 60,695 |
| 2021 | 411,458 | 62,212 |
| 2022 | 421,744 | 63,768 |
| 2023 | 432,288 | 65,362 |
| 2024 | 443,095 | 66,996 |
| 2025 | 454,172 | 68,671 |
| 2026 | 465,527 | 70,388 |
| 2027 | 477,165 | 72,147 |
| 2028 | 489,094 | 73,951 |
| 2029 | 501,321 | 75,800 |
| 2030 | 513,854 | 77,695 |
| 2031 | 526,701 | 79,637 |
| 2032 | 539,868 | 81,628 |
| 2033 | 553,365 | 83,669 |
| 2034 | 567,199 | 85,760 |
| 2035 | 581,379 | 87,904 |
| SUM | | 1,458,262 |

* = $(354,799 \times 0.42 \times 360)/1000$.

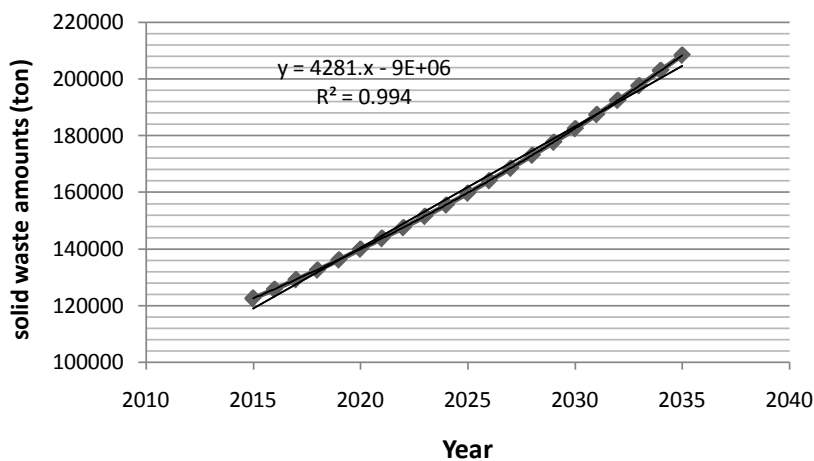


Figure 2. Expected solid waste in the Al-Najaf Qadhaa.

3) Al-Manathera Qadhaa

Amount solid waste based on the population and growth rate (Table 1) for Manathera Qadhaa for the period (2015-2035) is shown in Table 4 and Figure 4.

The accumulated domestic waste quantities for the coming twenty years for the three Qadhaas are illustrated in Table 5 and Figure 5.

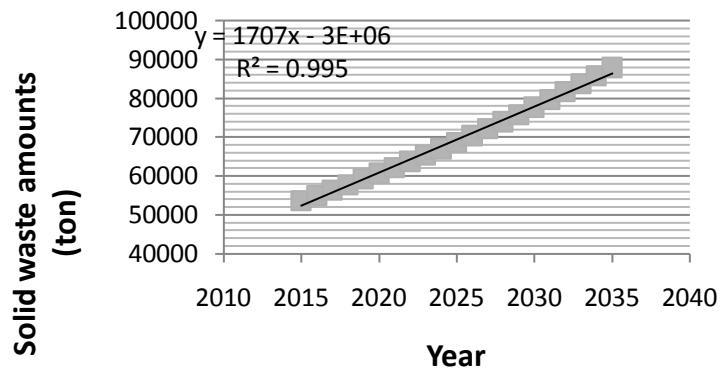


Figure 3. Population and solid waste in Al-Kufa Qadhaa.

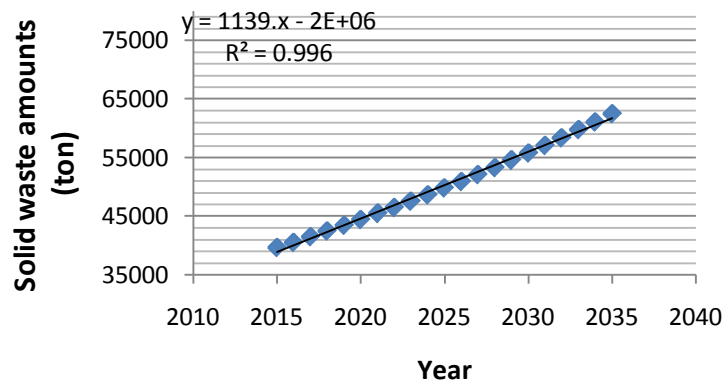


Figure 4. Solid waste in Al-Manathera Qadhaa with its population.

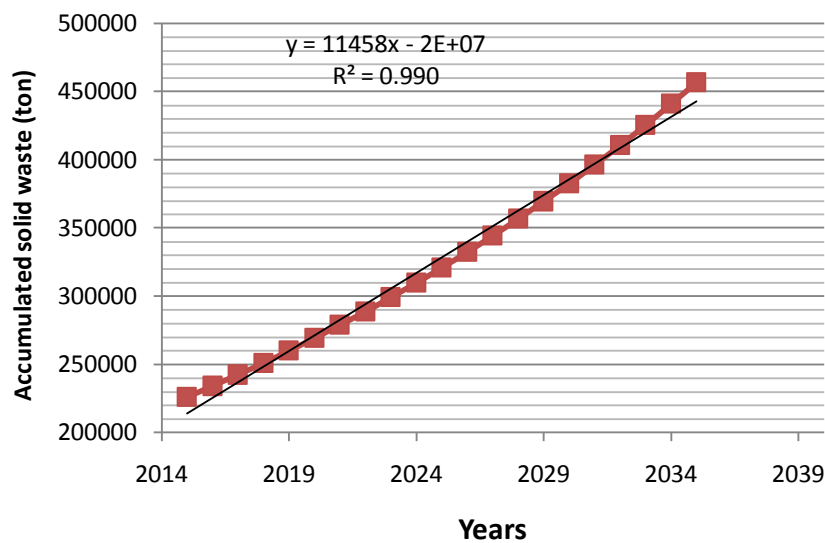


Figure 5. Accumulated solid waste quantities for Al-Najaf, Al-Kufa, and Al-Manathera Qadhaa with time.

Table 4. Solid waste in Al-Manathera Qadhaa with its population.

| Year | Population | Solid waste(ton) |
|------|------------|------------------|
| 2015 | 262,501 | *39,690 |
| 2016 | 268,538 | 40,603 |
| 2017 | 274,715 | 41,537 |
| 2018 | 281,033 | 42,492 |
| 2019 | 287,497 | 43,470 |
| 2020 | 294,109 | 44,469 |
| 2021 | 300,874 | 45,492 |
| 2022 | 307,794 | 46,538 |
| 2023 | 314,873 | 47,609 |
| 2024 | 322,115 | 48,704 |
| 2025 | 329,524 | 49,824 |
| 2026 | 337,103 | 50,970 |
| 2027 | 344,856 | 52,142 |
| 2028 | 352,788 | 53,342 |
| 2029 | 360,902 | 54,568 |
| 2030 | 369,203 | 55,823 |
| 2031 | 377,695 | 57,107 |
| 2032 | 386,382 | 58,421 |
| 2033 | 395,268 | 59,765 |
| 2034 | 404,359 | 61,139 |
| 2035 | 413,660 | 62,545 |
| | SUM | 1,056,251 |

* = $(262,501 \times 0.42 \times 360)/1000$.

According to the principle methods used for landfilling in dry areas it can be classified as: 1) Area, 2) Trench, and 3) depression. The adopted method in this research is the area method that is more suitable with Najaf environments lands of shallow ground water. Waste in the landfill should be covered daily in order to minimize health hazards and maintaining safety environment. The volume of daily cover in the landfill varies between 10% and 15% of the waste volume [7] [8]. Adopting a value of 12% of the waste volume, the accumulated weights and volume of waste for each Qadhaa and the required capacity of each landfill over the next twenty years can be estimated as shown in **Table 6** and **Table 7**.

4. Conclusions

Al-Najaf Governorate is located south-West Iraq. It covers an area of 28,824 square kilometers and its population in 2014 was 1,158,648 inhabitants. This city is visited regularly by what is called religious tourists. For this reason large quantities of solid waste are generated. In this research the generated solid waste was calculated based on the existing population and the expected population growth rate. This calculation was extended to 2035.

The total amount of solid waste was about 5,914,415 ton and the required landfill volume is 11,828,829 m³ to accommodate this waste. Qadhaa Al-Najaf solid waste generation was the highest relative to the other two Qadhaas

Table 5. The sum of the solid waste in twenty years for the three Qadhaas.

| Year | Solid waste (ton) in Al-Najaf Qadhaa | Solid waste (ton) in Al-Kufa Qadhaa | Solid waste (ton) in Al-Manathera Qadhaa | Total (ton) |
|-----------|--------------------------------------|-------------------------------------|--|-------------|
| 2015 | 122,518 | 53,646 | 39,690 | 215,854 |
| 2016 | 125,817 | 54,987 | 40,603 | 221,407 |
| 2017 | 129,205 | 56,361 | 41,537 | 227,103 |
| 2018 | 132,684 | 57,770 | 42,492 | 232,946 |
| 2019 | 136,258 | 59,215 | 43,470 | 238,943 |
| 2020 | 139,927 | 60,695 | 44,469 | 245,091 |
| 2021 | 143,696 | 62,212 | 45,492 | 251,400 |
| 2022 | 147,567 | 63,768 | 46,538 | 257,873 |
| 2023 | 151,542 | 65,362 | 47,609 | 264,513 |
| 2024 | 155,624 | 66,996 | 48,704 | 271,324 |
| 2025 | 159,817 | 68,671 | 49,824 | 278,312 |
| 2026 | 164,123 | 70,388 | 50,970 | 285,481 |
| 2027 | 168,545 | 72,147 | 52,142 | 292,834 |
| 2028 | 173,086 | 73,951 | 53,342 | 300,379 |
| 2029 | 177,750 | 75,800 | 54,568 | 308,118 |
| 2030 | 182,540 | 77,695 | 55,823 | 316,058 |
| 2031 | 187,460 | 79,637 | 57,107 | 324,204 |
| 2032 | 192,512 | 81,628 | 58,421 | 332,561 |
| 2033 | 197,700 | 83,669 | 59,765 | 341,134 |
| 2034 | 203,029 | 85,760 | 61,139 | 349,928 |
| 2035 | 208,502 | 87,904 | 62,545 | 358,951 |
| Sub.Total | 3,399,902 | 1,458,262 | 1,056,251 | 5,914,415 |

Table 6. The accumulated weighs and volume of waste for each Qadhaa.

| Qadhaa | Accumulated Waste from 2015 to 2035 Weight (ton) | Volume in Landfill (m ³)** |
|--------------|--|--|
| Al-Najaf | 3,399,902 | 6,071,254 |
| Al-Kufa | 1,458,261 | 2,604,038 |
| AL-Manathera | 1,056,251 | 1,886,163 |

**Density for compacting waste at landfill = 0.56 t/ m³ [9].

Table 7. Cumulative and compacted waste volumes for the landfills and its required areas.

| | Al-Najaf landfill | Al-Kufa landfill | AL-Manathera landfill |
|--------------------------------------|-------------------|------------------|-----------------------|
| Accumulated Volume (m ³) | 6,071,254 | 2,604,038 | 1,886,163 |
| +12% Cover | 728,550 | 312,484 | 226,339 |
| Total volume (m ³) | 6,799,804 | 2,916,523 | 2,112,502 |
| Area 2 m for 3 m depth | 2,266,601 | 972,174 | 704,167 |

simply because the religious tourists generate at least 342 ton.

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