

## Research Article

# Domestic Solid Waste Generation Rate Throughout 140 Continuous Days and Dissimilarity Between 2007 and 2021 in Erbil City

Shuokr Qarani Aziz 

Department of Civil Engineering, College of Engineering, Salahaddin University-Erbil, Erbil, Kurdistan Region, Iraq  
E-mail: shoker71@yahoo.com, shuokr.aziz@su.edu.krd

**Received:** 10 November 2022; **Revised:** 18 January 2023; **Accepted:** 8 February 2023

**Abstract:** Improper management of the domestic solid waste produced has a crucial impact on the environment. The quantity, components, and generation rate (GR) of domestic solid waste have been influenced by the population number, lifestyle, income, management, etc. This research is focused on the variation of a domestic solid waste GR for a duration of 140 continuous days, and the variation of GR between 2007 and 2021 for the same domestic solid waste was studied. Furthermore, the density of the domestic solid waste formed was examined as well. The domestic solid waste samples were collected constantly from 28 June 2021 to 14 November 2021. The domestic solid waste GRs for each day of the week were observed over a period of 20 weeks. The results show that the average GR and density in 2021 were 915.56 gram per capita per day (g/C/d) and 109.40 kg/m<sup>3</sup>, respectively. Whereas in 2007, GR and the density for the same family were 620.50 g/C/d and 124.98 kg/m<sup>3</sup>, correspondingly. GR from 2007 to 2021 has increased by 147.55%. The GR on holidays was higher than on the other days of the week. The recycling of cartons, plastics and metals in Erbil City reduced the density of domestic waste by 12.47% in 2021, thereby reducing the GR and the environmental pollution.

**Keywords:** density, generation rate, Erbil City, solid waste, treatment

## 1. Introduction

Erbil City is the capital of the Kurdistan Region, Iraq. The populations of Erbil City in 2007 and 2021 were 720,960 and 861,158, respectively [1]. The increase in population, the change in lifestyle, and the increase in income all had a great impact on the generation rate (GR) of solid waste. The amount of disposed municipal solid waste (MSW) in Erbil City is more than 2,000 tons per day [2]. Normally, MSW is disposed of at the Erbil landfill site. Recycling a part of the MSW has led to a decrease in the quantity and characteristics of MSW disposed at the Erbil landfill site. Nowadays, plastics, metals, cartons and tyres are recycled in Erbil City. The collected recyclable materials are used as raw materials for the new products [2]. Domestic waste, particularly garbage, is still collected and treated at the Erbil landfill site. To date, all kinds of waste in Erbil City are mixed together and disposed of in landfills. Therefore, domestic solid waste makes up a large part of the total amount of MSW. Domestic solid waste decomposes rapidly in the warm seasons, and it produces leachate and a nasty smell. In addition to that, the landfill leachate formed has contaminated surrounding soil and water sources [3]. On the other hand, the disposal of construction and demolition materials in various areas is creating environmental problems as well. Medical wastes, hazardous materials, and industrial materials

are sometimes mixed with the MSW and disposed of at the Erbil landfill site, which causes an environmental disaster. As a result, there is a necessity for proper management of domestic waste.

There have been a number of studies published on the quantity, characteristics, thermal production, composting and recycling of solid waste in Erbil City [2, 4-9]. Also, several pieces of research on domestic solid waste generation, MSW properties and management have been published in other provinces in Iraq [10-19]. Monney et al. [20] studied household solid waste characteristics in Wa, an urban community in Ghana. The researchers reported that the household waste GR for Wa was  $0.68 \pm 0.24$  kg/capita/day (kg/C/d) with a mean bulk density of  $44.9 \pm 28$  kg/m<sup>3</sup>. The characterization, GR, and management of household solid waste in Tulsipur, Nepal, were studied by Dangi et al. [21]. The authors stated that the GR of the household solid waste in Tulsipur was 330.4 gram per capita per day (g/C/d) [21]. Adamcová et al. [22] examined household solid waste components and hazardous waste in the Kuchyňky landfill. The results have shown that the portion of the household hazardous waste determined in Kuchyňky landfill was 2.047% of the total MSW [22]. In San Quintín and Vicente Guerrero, Mexico, the GR for household solid waste was 0.631 and 1.047 kg/C/d, respectively. Meanwhile, the uncompacted densities for the household solid waste were 145 and 123 kg/m<sup>3</sup>, respectively [23]. Shekha [7] collected 184 samples of household solid waste in Erbil City. The author declared that GR was 0.420 kg/C/d [7]. Al-Rawi et al. [11] collected 1,680 solid waste samples, and they reported that the GR of the solid waste in Mosul City, Iraq, was 0.60 kg/C/d, but Ali et al. [14] collected 1,155 domestic solid waste samples in Tuz Khurmatu District, Kirkuk Province, Iraq. The researchers concluded that GR and the density for the domestic solid waste samples were 0.574 kg/C/d and 140.3 kg/m<sup>3</sup>, respectively [14]. A study was conducted on solid waste in Sulaimania Province, Kurdistan Region, Iraq, by Hama et al. [17]. The range of GR for the 300 collected solid waste samples was 1 to 2 kg/C/d [17]. Generally, GR and the density of the produced solid wastes are affected by the characteristics of the solid waste, the recycling, the lifestyle, the income of the individual, the rural and urban areas, and the solid waste management [5-6].

Recently, Hamza et al. [24] published research on the application of Geographic Information System (GIS) to solid waste disposal locations and environmental impacts in the Kurdistan Region of Iraq. Also, new methodologies for MSW recycling and management in Erbil City were studied by Aziz et al. [25]. However, there is no published work on GR and the density of domestic solid waste during 140 continuous days. Moreover, there is no such comparison between the characteristics of solid waste in 2007 and 2021 in Erbil City and other provinces in Iraq. The current research objectives were to: 1) study the GR and density of produced domestic waste in Erbil City throughout 140 days in 2021; and 2) compare the GR and density of domestic solid waste for the same family in 2007 and 2021.

## 2. Materials and methods

### 2.1 Study area and data collection

Domestic solid waste samples have been collected at the house from New Zanco Village, Erbil City, the Kurdistan Region, Iraq. Figure 1 illustrates the study area. GR data was collected from 28 June 2021 until 14 November 2021 (i.e. 140 days or 20 weeks). Solid waste samples were collected on a daily basis. All kinds of domestic waste, such as garbage, glasses, and leaves, were mixed together in plastic bags and disposed of daily in the trash can in front of the house. The collected waste was weighed prior to disposal in the trash can. Private company vehicles have collected domestic waste between two and three times per week. Some types of waste, like cartons, plastics and metals, have been separated from domestic waste and then collected by individuals for recycling. The recycled solid waste materials were then disposed of separately and not included in this research.

For one household, 25 domestic solid waste samples were used in 2007. The domestic solid waste data for 2007 and 2021 were put together in a group for the same family. The fact that there was data available for the same source (i.e., same family) in 2007 and the data collected in 2021 enabled us to compare the domestic solid waste data between 2007 and 2021. There were 72 domestic solid waste samples that had been collected for different families in Erbil City in 2007. Meanwhile, only 25 solid waste samples from the same family in 2007 were compared with the accumulated data in 2021. The remaining collected samples (i.e., 47 samples) belonged to other sources (families), and they couldn't be used in the current research. Following the examination of the present work, the GR and density values for the same family in 2007 and 2021 were determined. The GR and the density of domestic waste in 2007 and 2021 have been

studied.



Figure 1. Map of New Zanco Village and Erbil City

## 2.2 GR and density determination

Domestic solid waste from New Zanco Village was collected and weighed daily for 140 days. The GR for the collected samples was calculated using the following equation [5, 14, 16, 26]:

$$GR = \frac{\text{Weight of collected solid waste (g)}}{\text{Population} \times \text{Duration}} \quad (1)$$

Meanwhile, the density of some collected samples has been calculated by applying the following formula [5, 14, 26]:

$$\text{Density} = \frac{\text{Weight of collected solid waste (kg)}}{\text{Volume (m}^3\text{)}}$$

## 3. Results and discussions

### 3.1 Domestic solid waste GR and density

Figure 2 illustrates the details of the domestic solid waste GR during 140 days. The minimum and maximum values for the GR were 150 and 5,873 g/C/d, respectively. Whereas, the average GR figure for the 140 collected samples was 915.56 g/C/d. Two GR peaks with values of 5,873 and 4,730 g/C/d can be observed in Figure 2; these two abnormal figures belonged to maintenance works in the kitchen, the arrangement and the cleaning of the garden. On 4 September 2021, maintenance of some parts and fixtures in the kitchen and discarded materials (such as pipes, fittings, tiles, etc.) led to a high GR of 5873 g/C/d. Furthermore, the cleaning of the garden and the collection of leaves and trees resulted in a high GR of 4,730 g/C/d on 18 October 2021. Aziz [5] reported that the average GR values for 72 domestic solid waste samples in Erbil City were 664 g/C/d. However, Shekha [7] stated that the average GR value for 180 household solid waste samples was 420 g/C/d. Al-Anbari et al. [12] reported that the GR of MSW in Najaf City, Iraq, was 420 g/C/d. According to Alkaradaghi et al. [16], the MSW GR in Sulaimani Governorate will be 1,320 g/C/d by 2040. In

Baghdad City, MSW GR in 2017 was 673 g/C/d [13], while MSW GR in Mosul City was 600 g/C/d [11]. Hamza [15] reported that MSW GR in Pshdar District, Sulamiani Governorate, was 671 g/C/d. MSW GR for a number of districts in Baghdad City ranged from 300 to 800 g/C/d [10]. Ali et al. [14] concluded that the GR and density of domestic solid waste in Tuz Khurmatu District, Kirkuk City, were 574 g/C/d and 140.3 kg/m<sup>3</sup>, respectively. The average solid waste GR in Baqubah City and Diyala Governorate, Iraq, was 560 g/C/d [14]. It can be noticed that the MSW GR in Erbil City is very close to that in the Iraqi provinces but higher than the global and regional MSW GR values [19]. The variation of GR values in Iraqi provinces and those between Iraq and Japan are a result of different incomes, awareness, lifestyles, recycling of solid waste, and solid waste management strategies [19, 25, 26].

The GR for household solid waste in Wa, Ghana, was 0.68 ± 0.24 kg/C/d [20], whereas in Tulsipur, Nepal, the GR was 330.4 g/C/d. In San Quintín and Vicente Guerrero, Mexico, the GR for household solid waste was 0.631 and 1.047 kg/C/d, respectively. The range of GR for the 300 collected solid waste samples in Sulaimania Province, Kurdistan Region, Iraq, varies from 1 to 2 kg/C/d [17]. Commonly, the available data in the extant literature confirmed the obtained GR data in 2021.

The density values for some domestic solid waste samples in 2021 are shown in Table 1. The average density value of some selected samples was 109.40 kg/m<sup>3</sup> in 2021. Aziz [5] concluded that the mean density value for 72 chosen domestic solid waste samples was 175.72 kg/m<sup>3</sup>. Ali et al. [14] reported that the density of domestic solid waste in Tuz Khurmatu District, Kirkuk City, was 140.3 kg/m<sup>3</sup>. In Wa, Ghana, the average bulk density for household solid waste was 44.9 ± 28 kg/m<sup>3</sup> [20]. Uncompacted densities for household solid waste in San Quintín and Vicente Guerrero, Mexico, were 145 and 123 kg/m<sup>3</sup>, respectively [23]. Some published figures confirmed the obtained results in the present work. Whilst comparing to other documented results, the lower density figures in the present research may be due to the recycling and also to the exclusion of some materials such as metals, plastics and cartons.

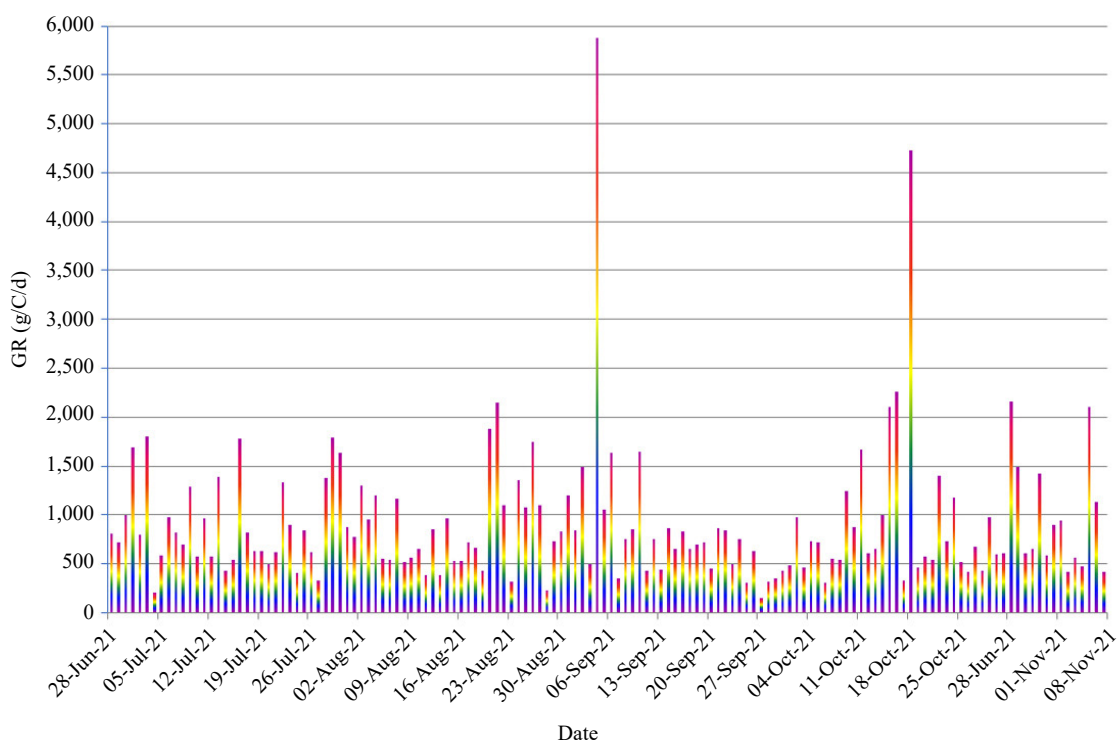


Figure 2. Variation of domestic solid waste GR during 140 days

**Table 1.** Density values for some domestic solid waste samples in 2021

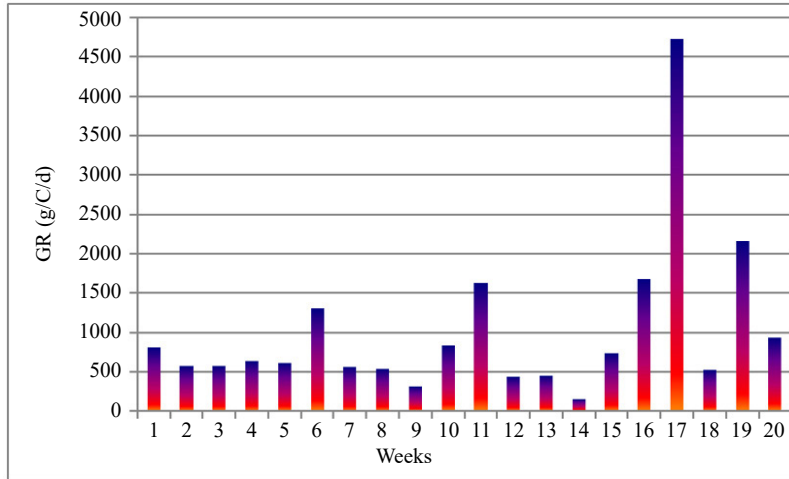
No.	Sample number	Weight (gram)	Volume (m <sup>3</sup> )	Density (kg/m <sup>3</sup> )
1	63	1330	0.011846	112.272
2	64	1660	0.009653	171.976
3	80	1310	0.01548	84.625
4	81	1665	0.016512	100.836
5	82	1140	0.016512	69.041
6	83	1335	0.016512	80.850
7	87	1690	0.016512	102.350
8	89	1515	0.013932	108.743
9	91	1085	0.016512	65.710
10	106	3345	0.016512	202.580
11	111	1135	0.014448	78.558
12	119	1875	0.017028	110.113
13	125	1135	0.013932	81.467
14	127	1225	0.01548	79.134
15	128	2980	0.013932	213.896
16	133	1365	0.01548	88.178

Average: 109.40

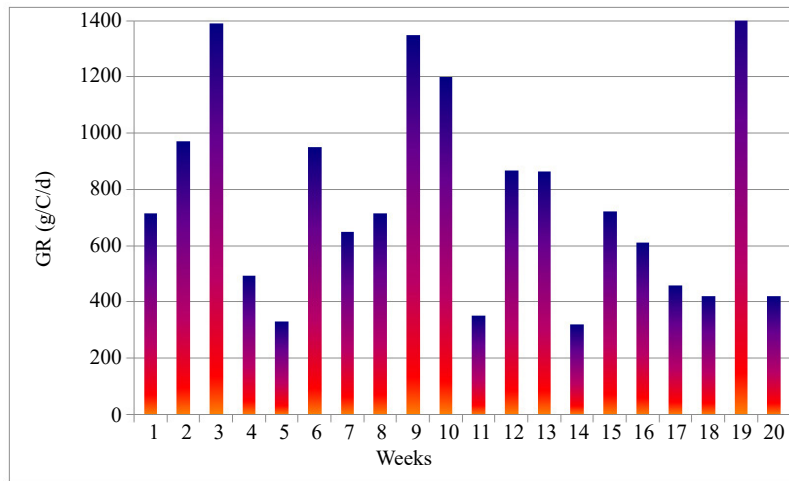
### 3.2 Variation of domestic solid waste GR during the days of the week

Variations of domestic solid waste GR on each day of the week during the study period are shown in Figures 3 to 9. Additionally, average GR values for each day of the week during the 20 weeks are given in Table 2. It can be observed that the GR of solid waste on the same days over the course of 20 weeks is frequently close to each other. Some fluctuations noticed are due to maintenance, cleaning of homes and gardens, and guests. In Erbil City and other provinces in Iraq, Friday and Saturday are holidays. Solid waste GR values on Friday and Saturday were 1,144 and 1,189 g/C/d, respectively (Table 2). Produced waste on holidays was higher than the average GR value (915.56 g/C/d). A minimum GR value of 711 g/C/d was reported on Sunday because it is the first working day in Erbil City (Table 2). The minimum GR was 150 g/C/d due to having meals outside the home. Commonly, GR values for Saturdays, Sundays, Tuesdays and Wednesdays were lower than the other days of the week. Here in Erbil City, the amount of domestic solid waste produced on Thursdays was high due to people purchasing a lot of things and preparing for the holidays (i.e., Friday and Saturday). This phenomenon is related to the customs and traditions of the community and to the presence of fresh fruits, vegetables, and chickens in the shops on Thursday and not on Friday. Most local shops and mini markets close on Friday.

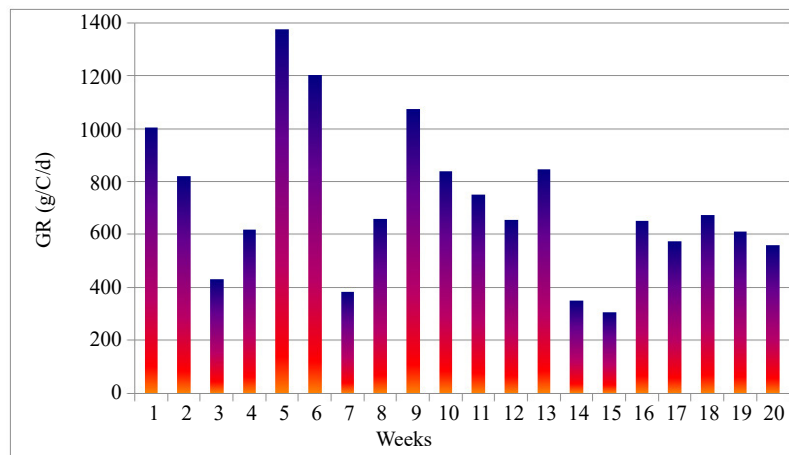




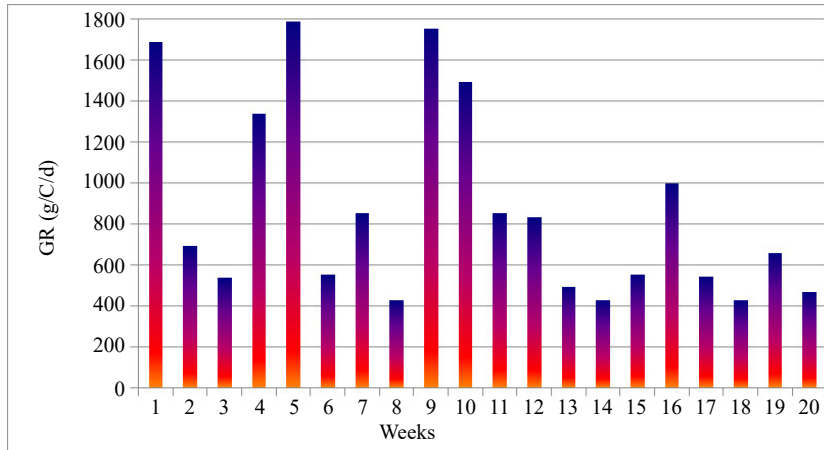
**Figure 3.** Variation of domestic solid waste GR on Mondays for the duration of 20 weeks



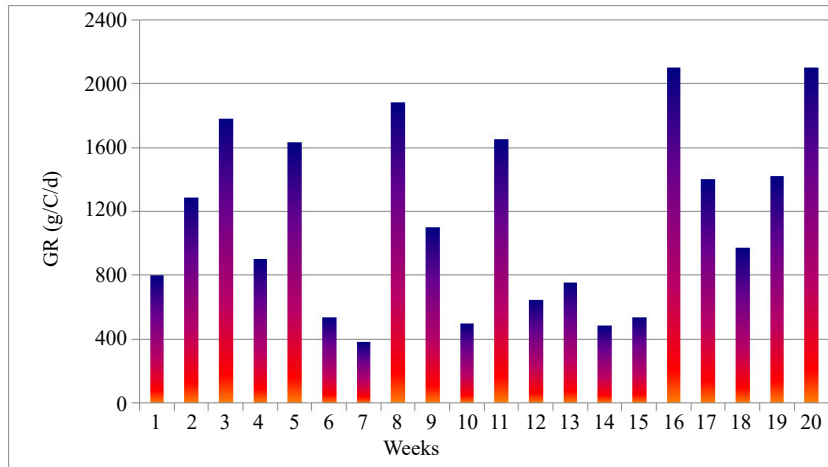
**Figure 4.** Variation of domestic solid waste GR on Tuesdays for the duration of 20 weeks



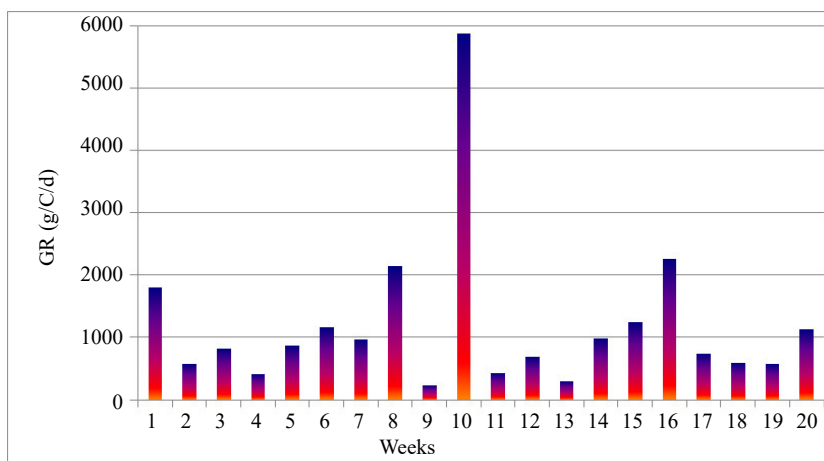
**Figure 5.** Variation of domestic solid waste GR on Wednesday for the duration of 20 weeks



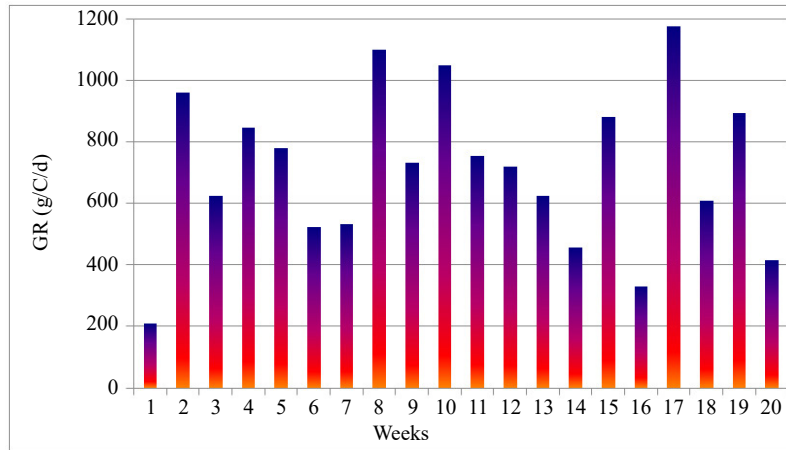
**Figure 6.** Variation of domestic solid waste GR on Thursday for the duration of 20 weeks



**Figure 7.** Variation of domestic solid waste GR on Fridays for the duration of 20 weeks



**Figure 8.** Variation of domestic solid waste GR on Saturdays for the duration of 20 weeks



**Figure 9.** Variation of domestic solid waste GR on Sundays for the duration of 20 weeks

**Table 2.** Average GR values for each day of the week for the duration of 20 weeks

No.	Day	Average GR (g/C/d)
1	Monday	1009
2	Tuesday	765
3	Wednesday	719
4	Thursday	867
5	Friday	1144
6	Saturday	1189
7	Sunday	711

### 3.3 Dissimilarity of GR and density between 2007 and 2021

The variations of domestic solid waste GR in 2007 and 2021 are shown in Figures 2 and 10. The population of Erbil City has increased by 1.194% between 2007 and 2021. Average domestic solid waste GR values for the same family in 2007 and 2021 were 620.5 and 915.56 g/C/d, respectively. It can be noticed that GR increased by 147.55% between 2007 and 2021, which is most likely influenced by lifestyle, needs, and income. The direction of the results is consistent with published data in the literature [19]. Average values for the density of domestic solid waste for the same family in 2007 and 2021 were 124.98 and 109.40 kg/m<sup>3</sup>, respectively. The recycling of cartons, plastics and metals in Erbil City decreased the density of domestic waste by 12.47% in 2021.

The standard deviation, average, and correlation between GR data in 2007 and 2021 are given in Table 3. The standard deviation for GR values in 2007 was 203.856. For the purpose of comparison with the 25 collected samples in 2007, the data in 2021 were distributed to six groups (Table 3). The GR for Group 4 (Sample Numbers 76 to 100) in 2021 was similar to the data collected in 2007. The GR values for all sets in 2021 were higher than the GR values in 2007, except for one group (Table 3). Some disposed materials, such as cartons, plastics, and metals, were recycled in Erbil City in 2021, which decreased the GR and density of the domestic solid waste [25]. Otherwise, the GR and density will be very high when compared to 2007.



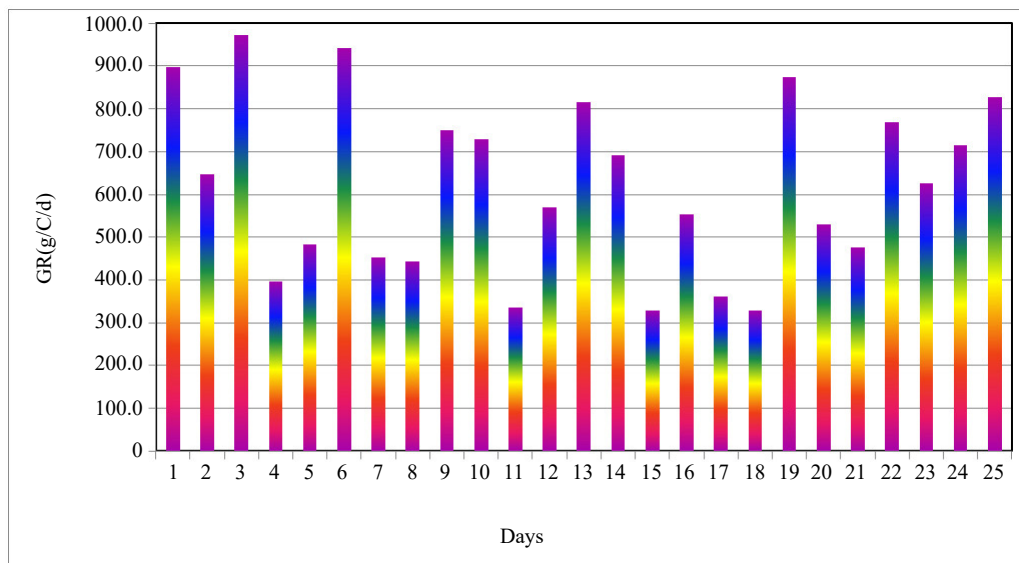


Figure 10. Domestic solid waste GR values in 2007

Table 3. Standard deviation, average and correlation between data in 2007 and 2021

	Collected samples in 2021	Standard deviation	Average GR	Correlation with GR in 2007
GR in 2021	Group 1 (1 to 25)	430.092	886	0.412
	Group 2 (26 to 50)	396.987	825	-0.013
	Group 3 (51 to 75)	1097.400	1220	0.112
	Group 4 (76 to 100)	213.431	600	0.122
	Group 5 (101 to 125)	934.660	1014	0.128
	Group 6 (126 to 140)	582.149	963	

## 4. Conclusions

GR and density for the collected domestic wastes during 140 days were 915.56 g/C/d and 109.40 kg/m<sup>3</sup>, respectively. Whereas in 2007, GR and density for the same family were 620.5 g/C/d and 124.98 kg/m<sup>3</sup>, congruently. GR for domestic solid waste from 2007 to 2021 increased by 147.55%. Lifestyle, income, and daily life requirements increased the GR of domestic solid waste. The GR during the holidays was greater than the GR for other days in the week. Due to the recycling of cartons, plastics and metals in Erbil City, the density of domestic waste in 2021 decreased by 12.47%. Mixed domestic solid waste influenced the environment. Recycling cartons, plastics, and metals decreased GR, density and environmental pollution. For future plans, it is proposed to separate solid waste into organic, plastic, carton, glass, and hazardous wastes. Later, factories can use the separated materials as raw materials. Additionally, composting is recommended for organic waste. Improvement of the present landfill, energy production and collection of the emitted methane gas are also suggested.

## Conflict of interest

There is no conflict of interest for this study.

## References

- [1] World Population Review. *Erbil Population*. <https://worldpopulationreview.com/world-cities/erbil-population> [Accessed 23rd July 2022].
- [2] Aziz SQ, Ismail SO, Omar IA. Recyclable solid waste materials management in Erbil City-Iraq. *International Journal of Engineering Inventions*. 2019; 8(1): 57-62. <https://www.researchgate.net/publication/332411019>
- [3] Aziz SQ, Maulood YI. Contamination valuation of soil and groundwater source at anaerobic municipal solid waste landfill site. *Environmental Monitoring and Assessment*. 2015; 187(12): 755. <https://doi.org/10.1007/s10661-015-4971-y>
- [4] Sabir S. Domestic solid waste management in Erbil City and their effects on surface and sub-surface water. *ZANCO Journal of Pure and Applied Sciences*. 2002; 14(2): 61-70.
- [5] Aziz SQ. A quantitative study on domestic solid waste components in Erbil City. *ZANCO Journal of Pure and Applied Sciences*. 2009; 21(4): 59-71. <https://www.researchgate.net/publication/234793967>
- [6] Aziz SQ, Aziz HA, Bashir MJK, Yusoff MS. Appraisal of domestic solid waste generation, components, and the feasibility of recycling in Erbil, Iraq. *Waste Management and Research: The Journal for a Sustainable Circular Economy*. 2011; 29(8): 880-887. <https://doi.org/10.1177/0734242X10387462>
- [7] Shekha YA. Household solid waste content in Erbil City, Iraqi Kurdistan region, Iraq. *ZANCO Journal of Pure and Applied Sciences*. 2011; 23(3): 1-8. <https://www.researchgate.net/publication/271157635>
- [8] Aziz SQ, Mustafa JS. Thermal and financial evaluations of municipal solid waste from Erbil City-Iraq. In: Çelik B, Hasan BA, Awni M. (eds.) *4th International Engineering Conference on Developments in Civil & Computer Engineering Applications* (IEC 2018). Iraq: IEC; 2018. p.86-97. [https://www.researchgate.net/publication/323457594\\_Thermal\\_and\\_Financial\\_Evaluations\\_of\\_Municipal\\_Solid\\_Waste\\_from\\_Erbil\\_City-Iraq](https://www.researchgate.net/publication/323457594_Thermal_and_Financial_Evaluations_of_Municipal_Solid_Waste_from_Erbil_City-Iraq)
- [9] Aziz SQ, Omar IA, Mustafa JS. Design and study for composting process site. *International Journal of Engineering Inventions*. 2018; 7(9): 9-18. <http://www.ijejournal.com/papers/Vol.7-Iss.9/C07090918.pdf>
- [10] Alsamawi AA, Zboon ART, Alnakeeb A. Estimation of Baghdad municipal solid waste generation rate. *Engineering & Technology Journal*. 2009; 27(1): 81-95. [https://uotechnology.edu.iq/tec\\_magaz/volume272009/No.1.2009/reseraches/Text\\_7.pdf](https://uotechnology.edu.iq/tec_magaz/volume272009/No.1.2009/reseraches/Text_7.pdf)
- [11] Al-Rawi SM, Al-Tayyar TA. Solid waste composition and characteristics of Mosul City/Iraq. *Al-Mustansiriyah Journal of Science*. 2012; 23(8): 19-34. <https://www.iasj.net/iasj/article/93779>
- [12] Al-Anbari MA, Thameer MY, Al-Ansari N, Knutsson S. Estimation of domestic solid waste amount and its required landfill volume in Najaf governorate, Iraq for the period 2015-2035. *Engineering*. 2016; 8(6): 339-346. <https://doi.org/10.4236/eng.2016.86031>
- [13] Chyad TF. Solid waste generation and rate components percentage in Baghdad City. *Journal of Engineering and Sustainable Development*. 2016; 20(6): 1-11. <https://www.iasj.net/iasj/article/129738>
- [14] Ali SM, Ali YM, Faris MR. Characteristics of domestic solid wastes in the judiciary of Tuz Khurmatu/ Iraq. *Eurasian Journal of Science and Engineering*. 2017; 3(2): 224-229. <https://doi.org/10.23918/eajse.v3i2p224>
- [15] Hamza AA. Municipal solid waste quantity, ingredients, and site disposal problems in Pshdar district in Sulaimanyah: Iraqi Kurdistan region, Iraq. *Kufa Journal of Engineering*. 2020; 11(4): 1-18. <https://www.iasj.net/iasj/download/303b0391ef400c72>
- [16] Alkaradaghi K, Ali SS, Al-Ansari N, Ali, T, Laue J. Quantitative estimation of municipal solid waste in Sulaimaniyah governorate, Iraq. In: Ksibi M, Ghorbal A, Chakraborty S, Chaminé HI, Barbieri M, Guerriero G, et al. (eds.) *Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions*. 2nd ed. Cham, Switzerland: Springer; 2021. p.265-270. [https://doi.org/10.1007/978-3-030-51210-1\\_44](https://doi.org/10.1007/978-3-030-51210-1_44)
- [17] Hama AR, Tahir TA, Ali BJ. A study on solid waste generation, composition and management in Sulaimania City, Kurdistan region, Iraq. *IOP Conference Series: Earth and Environmental Science*. 2021; 779: 012049. <https://doi.org/10.1088/1755-1315/779/1/012049>
- [18] Shehab EQ, Mohammed ZB, Fattah MY. Estimation of the components of residential solid waste in Baqubah City and their generation rate. *Engineering and Technology Journal*. 2021; 39(3A): 440-452. <https://doi.org/10.30684/etj.v39i3A.1777>
- [19] Japan International Cooperation Agency, Yachiyo Engineering Co., Ltd. *Data collection study on solid waste management in Iraq*. Final Report Summary. Ministry of Construction and Housing and Municipalities and Public Work, Regional Ministry of Municipalities and Tourism in Kurdistan, Mayoralty of Baghdad, Basrah City and Erbil City. 2022. <https://openjicareport.jica.go.jp/pdf/12367264.pdf>
- [20] Monney I, Tiimub BM, Bagah HC. Characteristics and management of household solid waste in urban areas in Ghana: The case of WA. *Civil and Environmental Research*. 2013; 3(9): 10-21. <https://core.ac.uk/download/>

pdf/234677605.pdf

- [21] Dangi MB, Urynowicz MA, Belbase S. Characterization, generation, and management of household solid waste in Tulsipur, Nepal. *Habitat International*. 2013; 40: 65-72. <https://doi.org/10.1016/j.habitatint.2013.02.005>
- [22] Adamcová D, Vaverková MD, Stejskal B, Břoušková E. Household solid waste composition focusing on hazardous waste. *Polish Journal of Environmental Studies*. 2016; 25(2): 487-493. <https://doi.org/10.15244/pjoes/61011>
- [23] Taboada-González P, Armijo-de-Vega C, Aguilar-Virgen Q, Ojeda-Benítez S. Household solid waste characteristics and management in rural communities. *The Open Waste Management Journal*. 2010; 3: 167-173. <https://doi.org/10.2174/1875934301003010167>
- [24] Hamza AA, Mizzouri NS, Aziz SQ, Hawez DM, Manguri SBH, Ahmed KO, et al. GIS visualization of solid waste disposal sites and environmental impacts in Kurdistan region-Iraq. *Eurasian Journal of Science and Engineering*. 2022; 8(3): 169-187. <https://doi.org/10.23918/eajse.v8i3p169>
- [25] Aziz SQ, Ismael SO, Omar IA. New approaches in solid waste recycling and management in Erbil City. *Environmental Protection Research*. 2023; 3(1): 1-13. <https://doi.org/10.37256/epr.3120231758>
- [26] Davis ML, Cornwell DA. *Introduction to Environmental Engineering*. 5th ed. New York, United States: McGraw-Hill; 2008.