Journal of Environmental Sciences. Mansoura University, 2022; 51*(4)*, -. *doi: https://doi.org/10.21608/joese.2022.151780.1018*

Journal of Environmental Sciences

JOESE 5

ISSN 2090-9233

Journal homepage http://joese.journals.ekb.eg

Original Article

Challenges and Opportunities of Urban Solid Waste Management in Sulaymaniyah City

Sumaia M. Raheem[1], Hawall I. Rasul[1], and Hemin A. Neima[1*]

[1] Department of Agribusiness and Rural Development (ARD), College of Agricultural Engineering Sciences, University of Sulaimani, Sulaymaniyah City, Kurdistan Region of Iraq.

* Corresponding author: hemin.neima@univsul.edu.iq

Abstract:

One of the major worldwide environmental pollution concerns is the increase in waste generation due to the rapid world population growth and development which needs to be managed in an environmentally safe manner. How to manage solid waste has necessitated greater knowledge of the composition, generation quantity, physical properties, and impacts of economic aspects to protect the environment and step toward sustainable development. This study aims to investigate the municipal solid waste generation and estimate the future prediction of the cumulative solid waste amount with population growth by 2050 in Sulaymaniyah city, using brief calculations of the secondary data of solid waste generation for five years (from 2016 to 2020) collected from the Solid Waste Management Department, the General Directorate of The Municipality of Sulaymaniyah City, Kurdistan Region of Iraq. The results revealed that even though the population increased with an annual average growth rate of 1.99% and a change of 10.34%, solid waste generation has decreased with an annual average growth rate of - 2.29% and a change of -9.26%. Food waste had the highest rate of 64.3% in 2016 and continually augmented to 72.59% in 2020 with an increase in change rate of 12.89% and an average annual growth rate of 3.17 Additionally, based on the current and predicted population growth, the solid waste generation will increase by 129.20% to 1.053 Kg/(capita. day) in 2050, which will require a bigger area of the disposal site and better management in the future.

Keywords: Solid waste generation, Waste management, Food waste, Environmental pollution

1. Introduction

There is a growing concern about the environment around the world, and environmental commissioners are developing methods to introduce new environmental regulations and directives (Hakami, 2016). Domestic, agricultural, industrial, construction, biodegradable, non-biodegradable, biomedical, and hazardous wastes are all produced by human activities (Demirbas, 2011). These wastes can have an adverse impact on the environment, health and safety if not managed properly (NSWAI, 2013). Among the environmental pollutants, generating waste is faster than the greenhouse gases present (Srivastava *et al*., 2015). Socioeconomic development, industrialization degree, and climate affect the rate of waste generation (Hoornweg and Thomas, 1999). Accurate information about characterizing solid waste by its sources, the types of wastes produced and rates of generation and composition are important for observing and controlling the waste management system, in addition to making regulatory, financial and institutional decisions (Hoornweg and Thomas, 1999). The responsibility of each city's government to its residents is to provide solid waste management services, by employing local authorities to manage, treat and recycle waste (Hoornweg and Bhada-Tata, 2012). Waste management can be defined as the process of the collection, transport, processing, and recycling or disposal of waste materials (Demirbas, 2011). Furthermore, waste disposal management is a serious issue in the 21st century (Adhikari et al., 2000). Waste treatment technology is a crucial aspect of waste management (Hershaft, 1972). The development and application of municipal solid waste treatment technology rely on various socio-economic and environmental factors (Zaman, 2013). Nevertheless, treatment of each kind of waste depends on its type as different types of waste can create several environmental, health and socio-economic problems. These problems can be seen obviously in many developing countries in the world (Qdais, 2007). Improving principles of 3Rs (Reduce, Reuse, and Recycle) in the community has some advantages such as; reducing waste generation, declining expenditure on solid waste management (SWM), and minimizing the land that uses for waste disposal. Simultaneously, the sustainability of the environment and cooperative life improve the final disposal sites. In most low-income countries the implementation of this approach has not been improved due to the lack of reliable policies, low financial sustainability, and lack of public awareness (Ferronato *et al.*, 2017).

Although solid waste generation is highly imposing environmental pollution, fewer studies have been conducted to quantify solid waste generation in the Kurdistan Region of Iraq (KRI), such as Hama et al. (2021) determined the compositions of generating solid waste of Sulaimania city; Alkaradaghi, et al. (2021) studied the quantitative estimation of municipal solid waste in Sulaimaniyah Governorate; Aziz (2019) studied the recyclable solid waste materials in Erbil City; Rashid et al., (2018) investigated the

waste management in Chamchamal; and Shekha (2011) determined the quality and quantity of municipal solid waste of Erbil city.

Providing data on solid waste generation assists in providing information regarding quantity, composition, physical properties, and impacts of economic aspects that are required for waste management. Although the local authorities in Sulaimani city collect and transport the waste, the waste is mixed. They do not provide a bin for recycled waste. This old waste management system has a hugely adverse effect on human health and the environment (Jouhara *et al*., 2017). An outdated (old-style) method of reduction is considered unsustainable due to its lack of flexibility and long term thinking, while, sustainable waste management is focused on transferring the waste from disposal (Seadon, 2010). This study aims to evaluate the quantity and management of the current municipality's solid waste generation and estimate future solid waste generation until 2050, to suggest recommendations for future sustainable solid waste management.

2. Materials and Methods

2.1.1. Location and populations:

Sulaymaniyah is one of the major cities in the Kurdistan Region of Iraq (Figure 1), and its urban population is estimated at 829,245 in 2015 (Slemani.gov.krd, 2018). The estimated urban population of Sulaymaniyah city for each year from 2016 until 2020 were calculated with the following equation:

$P_t = P_o*(1 + r)^{\wedge n}$ …… (1)

Where:

P_t: Expected population for future

P_o: Current population

r: Annual growth rate (2.249%) (calculated based on available data between 2009-2015according to (UN, 1952))

n: Number of years

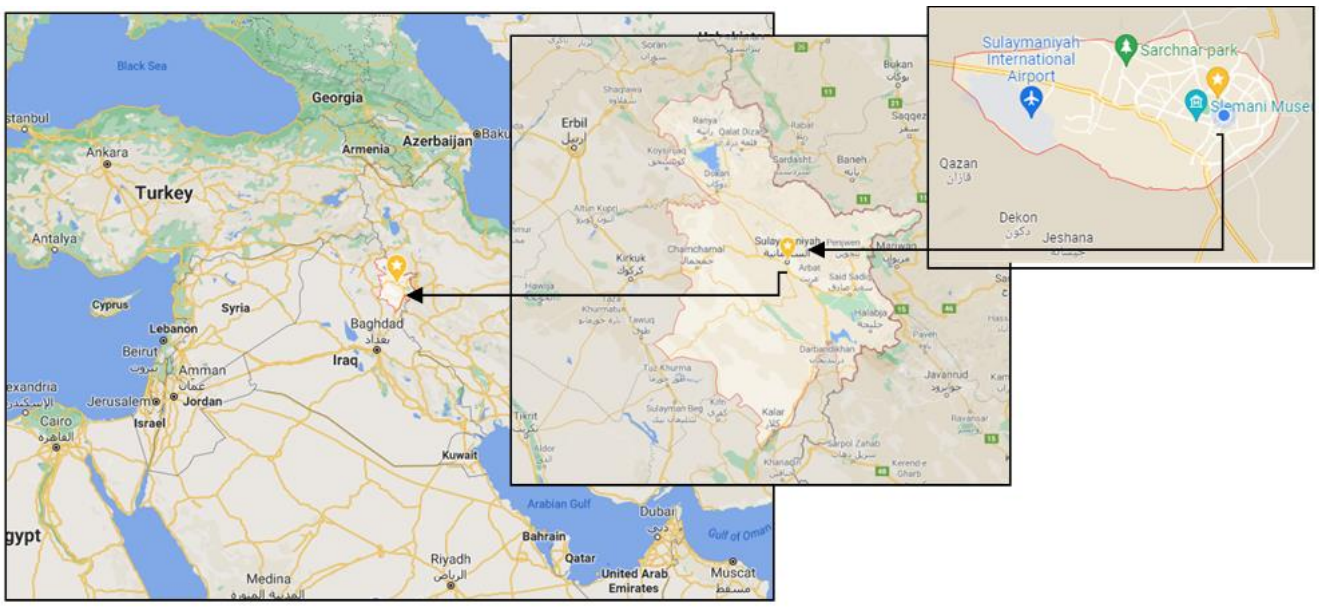

Figure 1. Map of Sulaymaniyah City (Source: Google Map)

2.2. Data Collection and Analysis:

The secondary data were collected from the Solid Waste Management Department, the General Directorate of the municipality of Sulaymaniyah City, Kurdistan Region of Iraq. The Municipality of Sulaymaniyah City has divided Sulaymaniyah city into six waste collection zones (Center Zone, West Zone, East Zone, Raparin and Bakrajo Zone, and other Manucipitality Zones).

In this study, the Growth Percentage, Growth Rate, and Average Annual Growth Rate indicators were used to determine trends in waste levels between 2016 to 2020. The growth percentage (Growth %) was calculated from the value of the generated waste at the end of the period of study minus the value of the generated waste at the start point of this study to the value of the generated waste at the end of the period of study, multiplying by 100. Change percentage can be calculated from the following equation (Parker, 2002; UNESCAPE, 2015):

$$\textbf{Change } \% = \left(\frac{\text{Ending Value} - \text{Beginning Value}}{\text{Beginning Value}}\right) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:

Change % = Change percentage between the start and end periods

The growth rate (GR) was calculated from the value of the generated waste at the end of the period of study to the value of the generated waste at the start point of this study, multiplying by

100. GR was calculated from the following equation (Parker, 2002; UNESCAPE, 2015)::

$$\mathbf{GR} = \left(\frac{\text{Ending Value}}{\text{Beginning Value}} - 1\right) \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

Where:

GR = Growth Rate

The average annual growth rate (AAGR) was calculated by measuring the average growth rates over several equal lengths of periods on an annualized basis (years). AAGR was calculated from the following equation (Parker, 2002; UNESCAPE, 2015)::

$$\mathbf{AAGR} = \frac{\sum \text{GRn}}{\text{N}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

Where:

AAGR = Average annual growth rate

GR_n = Growth rate in a period (e.g., year 1, year 2, etc.)

N = Number of Years

The predicted solid waste generation from (2021 to 2050) was calculated with the following Equation (Alkaradaghi, et al., 2021) based on the current and the predicted population growth and a calculated average solid waste generation rate of 0.9834 kg/(capita. per day) of available data (2016-2020) in Sulaimaniyah city.:

$$Q_{w(ct)} = ((P_t \times SWGR \times 365) / (1000)) + (Q_{w(av.)} - Q_{w(gsy.)}) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

Where:

Qw(ct): Expected future quantity of solid waste for a year (tonnes)

Pt: Expected future population number for a year

SWGR: Solid Waste Generation Rate [Kg /(capita. day)] (average between 2016-2020)

Qw(gsy.): The quantity of solid waste generated in 2020 (Kg)

Qw(av.): Average quantity of solid waste for the years 2016–2020 (Kg).

The collected and calculated data were analyzed with Microsoft Office Excel version 2019 and XLSTAT version 2016. Additionally, the analysis of variance with a confidence interval of 95% was applied to show the differences in average weights of SWGs within different years, months and zones.

3. Results and Discussion

The results in table (1) show the change and annual growth rates of generated solid waste and population growth in Sulaymaniyah city for five years from 2016 to 2020. The data shows that however the human population, in Sulaymaniyah city, has grown from 851,303 in 2016 to 945,560 in 2020 with an annual average growth rate of 1.99% and change of 10.34%, on the contrary, solid waste generation has decreased from 328,812 tonnes in 2016 to 298,353 tonnes in 2020 with annual growth rate - 2.29% and change of -9.26%. The daily solid waste generation (Kg/(capita. day) has considerably decreased by -17.77%, and -4.66% average annual growth rate.

Table 1. Annual growth rate and change percentage of the generated solid waste and human population in Sulaymaniyah city between 2016-2020

Year	Population Growth	Total solid waste (tonne)	Daily waste generation in Kilograms per capita
2016	849,893	328,812	1.060
2017	871,056	311,053	0.978
2018	892,745	315,072	0.967
2019	914,974	324,785	0.973
2020	937,757	298,353	0.872
Change %	10.34	-9.26	-17.77
Average Annual Growth Rate	1.99	-2.29	-4.66

Figure 2 illustrates the average solid waste generation per month for each year between 2016 to 2020 (tonne/month). Analysis of variance ANOVA was applied to find the differences between the means of solid waste generation per month. The results showed that there were significant differences between 2016 comparison to 2017 when the economic crisis peaked, and 2020 when the average weight per month (was 24,862.8 tonnes per month) that can be linked to the effects of the quarantine due to the spread of pandemics (Covid-19).

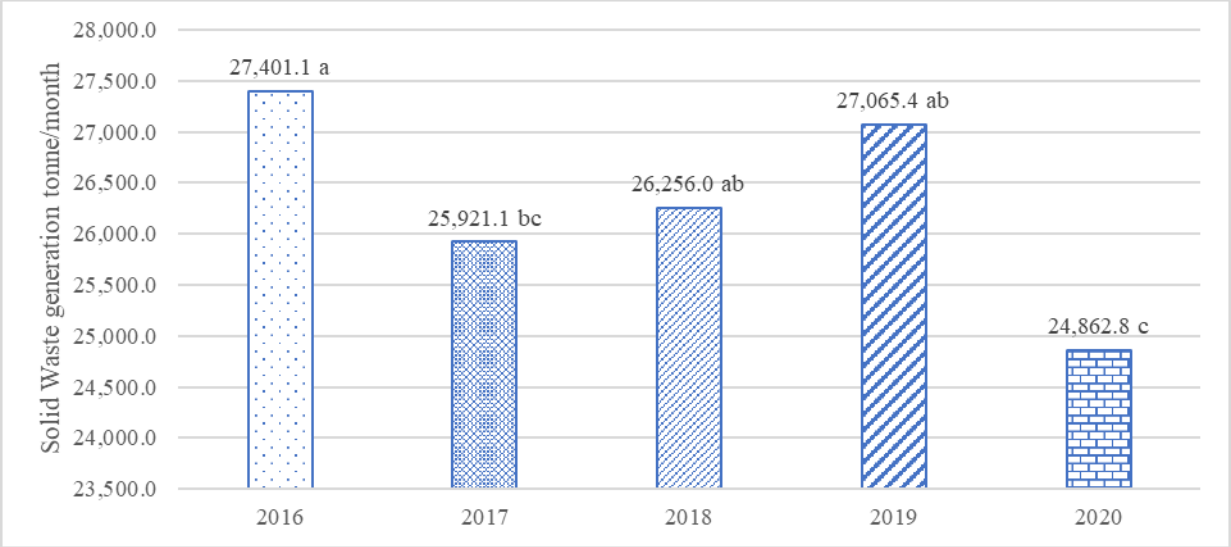

Figure 2. The yearly average weight of solid waste generation per month (tonne/month) [[a-c] Different letters on the columns show significant statistical differences (p<0.05)]

Figure (3) shows the results of the analysis of variance ANOVA applied to find the differences between the means of solid waste generation for five years. The highest amount of solid waste generation is recorded during the spring season in May (27,091.8 tonnes) and April (27,226.6 tonnes) while the lowest solid waste generation was recorded during the winter season, especially in February (24,622.8 tonnes) and then the autumn season, specifically in September (25,535.2 tonnes). In the KRI, most of the occasions are in the spring season, meanwhile, most people picnic starting from the first day of spring (Nawroz - 21st March). This leads to generating more solid waste, mainly food and plastic waste due to spending more on food, clothes, and disposable plastics.

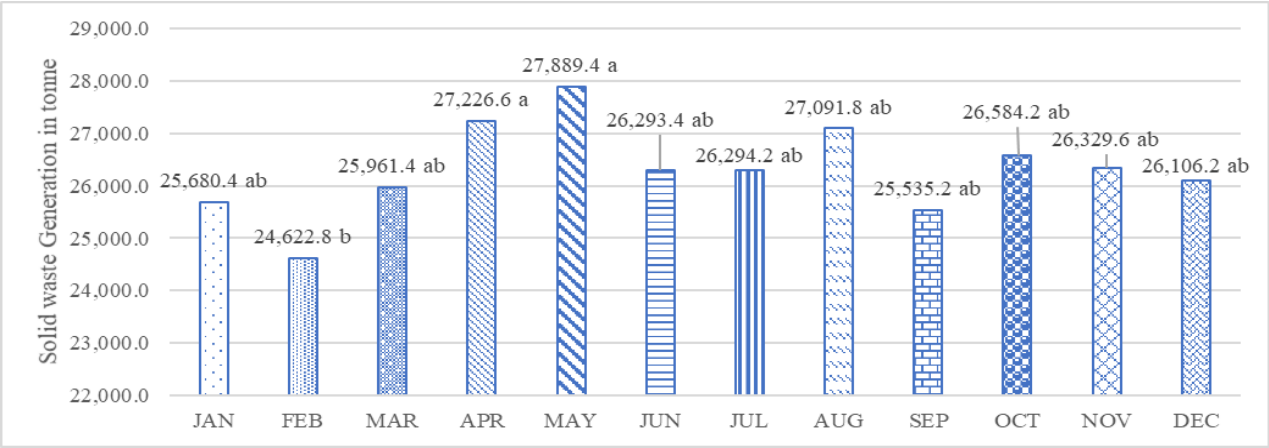

Figure 3. Average SWG weight of five years (from 2016 to 2020) [[a-b] Different letters on the columns show significant statistical differences (p<0.05)]

)

The results in table 2 show an analysis of variance for the average weight of solid waste generation for each zone per year. The centre zone, where Bazar is located and is populated with higher-income residents, had significantly higher solid waste generation (99,555.40 ± 2348.035tonne) in comparison to other zones. The significantly lowest solid waste generation was recorded in the municipality zone (28,981.60 ± 2348.035tonne) which is populated with lower-income residents.

Table 2. Analysis of variance for the average weight of solid waste generation per zone per month (2016-2020)

Zones	LS means	Std. Error
C	99,555.40 a	2348.035
W	89,010.20 b	2348.035
E	60,248.20 c	2348.035
RB	37,819.80 d	2348.035
MZ	28,981.60 e	2348.035

[a-e] Different letters in the same column shows significant statistical differences (p<0.05)

The predicted solid waste generation was calculated based on the current and the predicted population growth and a calculated average solid waste generation rate of 0.9652 kg/(capita. day) between 2016- and 2020 in Sulaymaniyah city. The results showed that the population will increase by 130.77%, meanwhile, solid waste generation is expected to be more than doubled with an increase of 129.20% to 1.053 Kg/(capita. day) by 2050 (See Fig. 4) which is less compared to Alkaradaghi et al. (2021) that estimated by 1.32 Kg/capita. day in 2040.

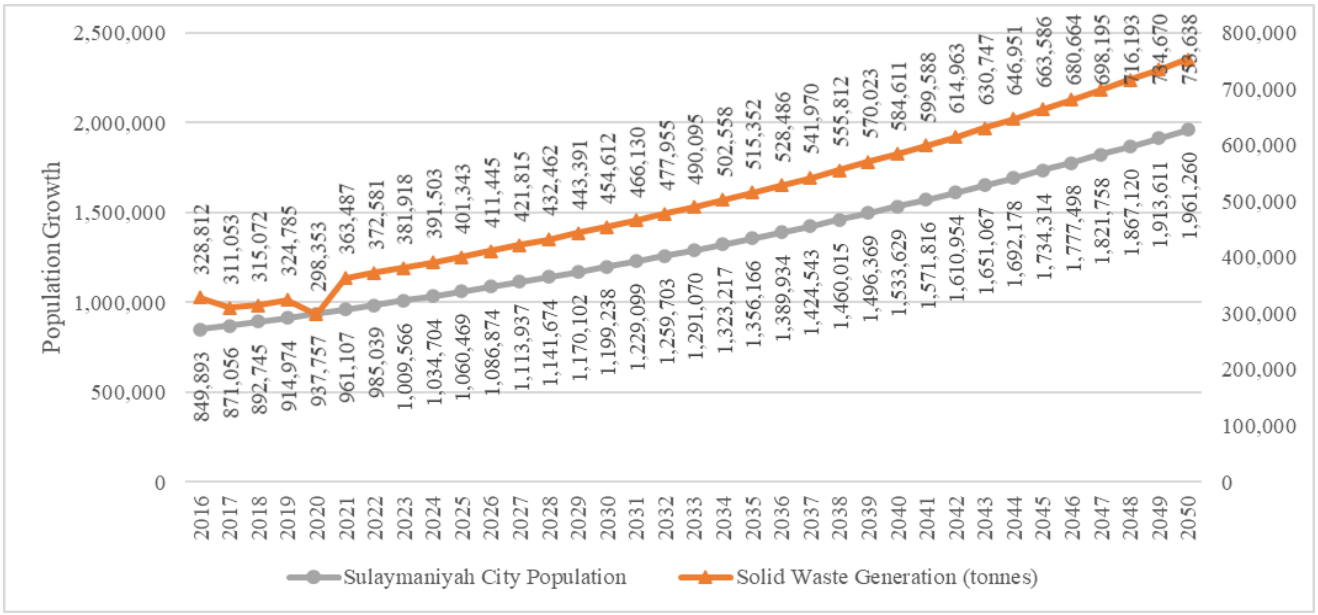

Figure 4. Predicted solid waste generation trends between until 2050

Table 3 shows the result of separating the solid waste into food, cardboard and paper, plastic, metals, glass, and others for five years. The results showed that food waste had the highest rate ranging between 64.3% in 2016 to 72.59% in 2020 with an increase in change rate of 12.89% and an average annual growth rate of 3.17. Similarly, Shekha (2011) recorded the highest share of food scraps (76%) in the solid waste composition in Erbil City. The lowest was glass that ranging between 1.98% in 2016 to 2.36% in 2020 with the increase in change rate 19.45% and average annual growth rate 6.04, followed by metals that ranged between 2.16% in 2016 and 3.49% in 2020 with an increase in change rate 61.70% and average annual growth rate 13.37. Moreover, it was noticed that the cardboard and papers, and plastic wastes collected and thrown by the municipality were decreasing ranged between 4.77%, and 11.27%, respectively in 2016 to 3.78%, and 6.17% in 2019, respectively, with a change rate of - 20.78%, and - 45.28% and average annual growth rate -4.60%, and -13.27%, respectively. These decreases can be related to the demand for those materials by the small recycling factories. The demanded recyclable solid waste items (mainly cardboards, plastics, cans, and glass bottles) are collected and transferred to the small recycling factories by poor individuals to make their living income (Figure 5a&b).

Table 3. The composition of solid waste in Sulaymaniyah city between 2016-2020 (%)

Year	Total waste sample	Food Waste	Cardboard and papers	Plastic	Metals	Glass	Others
2016	2,211,109	64.30	4.77	11.27	2.16	1.98	15.53
2017	2,277,442	63.09	5.43	10.23	2.86	2.72	15.68
2018	2,345,765	68.86	5.03	8.81	3.10	2.39	11.82

2019	2,416,138	72.59	3.78	6.17	3.49	2.36	11.61
Change %	9.27	12.89	-20.78	-45.28	61.70	19.45	-25.21
Average Annual Growth Rate	2.25	3.17	-4.60	-13.27	13.37	6.04	-6.35

a. A middle-aged man collecting cardboard for recycling **b.** Children collecting recyclable plastic for recycling

Figure 5. Collection of the recyclable materials by individuals for small recycling factories

The generated solid waste in Sulaymaniyah city is supposed to be either recycled or land-filled but most of it is openly dumped without any treatment in the Tanjaro site (see Figure 6) which is 20.8km away from the Sulaymaniyah city centre. This has already caused pollution in this area (Hama et al., 2021) and mainly water pollution of the Tanjaro river (Othman et al, 2021). If the municipality of Sulaymaniyah continues with the current ineffective collection technique and dumping in the current disposal sites (Tanjaro), the expected increase in the future generated solid waste more than double by 2050, will pose serious environmental pollution and risk to human health.

Figure 6. Photos of the Tanjaro Solid Waste Dumping Site

The results indicated that about three-fourths of the generated solid waste composition was food waste and it is predicted to increase continuously. Food waste causes serious pollution and waste of natural resources (Footprint, 2022; Jaglo et al., 2021; Baig et al., 2019; and Hall, et al., 2009). Therefore, the Kurdistan Regional Government (KRG) need to step toward a zero food waste policy through source reduction, feeding the hungry, feeding animal, composting and land-fill. To achieve this goal most importantly is working on the rise of people's awareness to reduce food loss and food waste through either governmental or non-governmental organizations.

Sulaymaniyah municipality has not applied source-separated collection in its solid waste treatment itinerary yet (see Figure 7). This means all solid waste items are mixed in the current collection method in Sulaymaniyah city. Basically, an effective method of recycling waste items begins with sorting and separating waste at the source. Sorting before collection needs creating public awareness and education to raise the public concern about solid waste removal and believe that there are advantages to sorting

waste before removal. Additionally, the Sulaymaniyah city municipality needs to implement an integrated disposal system by improving waste collection systems, choosing proper separation and collection methods and; implementing an integrated disposal method that includes: recycling, incineration and sanitary land-fill. To achieve this goal, there is more potential in recycling and encouraging the involvement of the private sector.

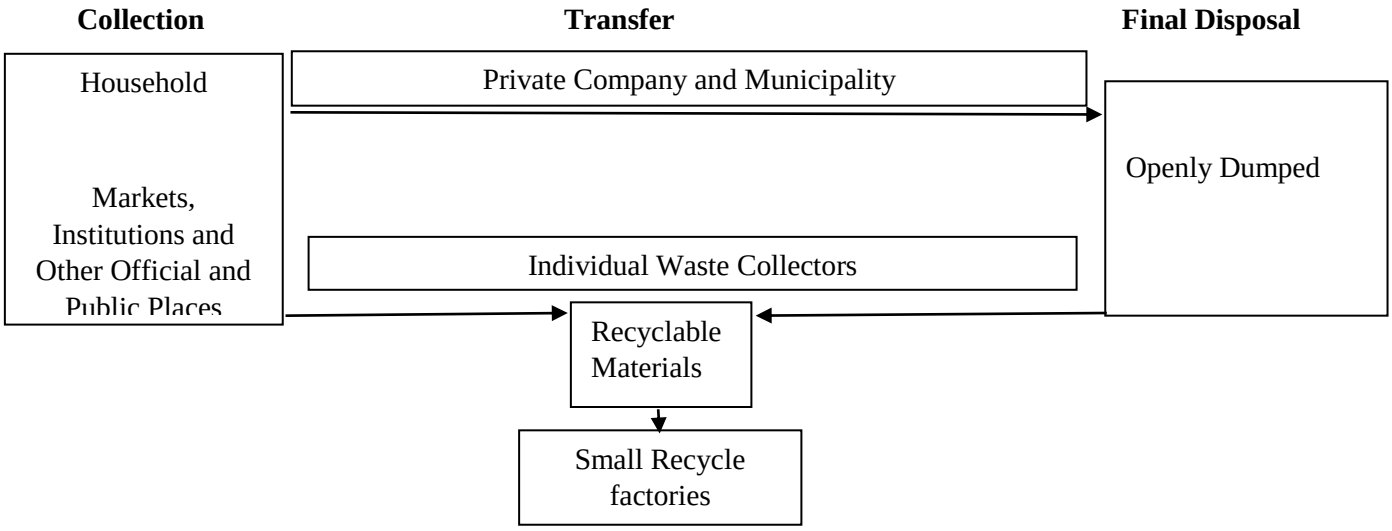

Figure 7. Solid waste treatment itinerary of Sulaymaniyah City Municipality

4. Conclusion

In conclusion, this study revealed a decrease in the solid waste generation between 2016-and 2020 and mostly open dumped or landfilled in the Tanjaro area that created a serious threat of environmental pollution and human health hazards. It is predicted that solid waste generation will be doubled in 2050, based on the estimated population growth in Sulaymaniyah city. This will require a bigger area of the disposal site and better management in the future. It is also observed that food waste had the highest percentage of the solid waste generated in Sulaymaniyah city.

Overall, it can be said that there is a serious threat of environmental pollution and human health hazards due to the current ineffective collection technique, dumping in the Tanjaro disposal sites, and the predicted increase in the future generated solid waste (mostly food waste), due to the population growth rate and per capita, solid waste generation, will pose further risks. Therefore, stepping toward a zero food waste policy is urgently need to be taken through public awareness creation to reduce food loss and food waste.

5. Acknowledgement

Assistance provided by the Solid Waste Management Department, the General Directorate of the Municipality of Sulaymaniyah City during data collection is greatly appreciated.

6. Conflicts of Interest

The authors declare no any source of fund and potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

7. References

1. Adhikari, B., De, D., and Maiti, S. 2000. Reclamation and recycling of waste rubber. *Progress in polymer science*, 25(7), 909-948.
2. Alkaradaghi K., Ali S.S., Al-Ansari N., Ali T., Laue J. 2021. Quantitative Estimation of Municipal Solid Waste in Sulaymaniyah Governorate, Iraq. In: Ksibi M. et al. (eds) Recent Advances in Environmental Science from the Euro-Mediterranean and Surrounding Regions (2nd Edition). EMCEI 2019. Environmental Science and Engineering. Springer, Cham. DOI: https://doi.org/10.1007/978-3-030-51210-1_44 .
3. Aziz, Sh. Q., Ismail, S. O. and Omar, I. A. 2019. Recyclable Solid Waste Materials Management in Erbil City- Iraq. *International Journal of Engineering Inventions*, 8,(1), 57-62
4. Baig, M. B., Al-Zahrani, Kh. H., Schneider, F., Straquadine, G. S., and Mourad, M. (2019). Food waste posing a serious threat to sustainability in the Kingdom of Saudi Arabia – A systematic review, Saudi Journal of Biological Sciences, 26, 7, 1743-1752. (DOI: https://doi.org/10.1016/j.sjbs.2018.06.004).
5. Demirbas, A. 2011. Waste management, waste resource facilities and waste conversion processes. *Energy Conversion and Management*, 52(2), 1280-1287.
6. Ferronato, N., D'Avino, C., Ragazzi, M., Torretta, V. and De Feo, G. 2017. Social surveys about solid waste management within higher education institutes: A comparison. *Sustainability*, 9(3), p.391
7. Footprint. 2022. The Problem of Food Waste. [Acceed on 6/4/2022], [Available at: https://foodprint.org/issues/the-problem-of-food-waste/].
8. Hakami, B.A. 2016. Environmental externalities from landfill disposal and incineration of waste. *International Journal of Advanced Research in Engineering and Technology*, *7*(1), p.201.
9. Hall, K. D., Guo, J., Dore, M., and Chow, C.C. (2009). The Progressive Increase of Food Waste in America and Its Environmental Impact. *PLoS ONE* 4(11): e7940. (DOI: https://doi.org/10.1371/journal.pone.0007940)
10. Hama, A. R., Tahir, T. A. 2 and Ali, B. J. 2021. A study on solid waste generation, composition and management in Sulaimania city, Kurdistan region, Iraq. *IOP Conf. Series: Earth and Environmental Science* 779 (2021) 012049. doi:10.1088/1755-1315/779/1/012049
11. Hershaft, A. 1972. Solid waste treatment technology. *Environmental Science & Technology*, 6(5), 412-421.

12. Hoornweg, D. and Thomas, L., 1999. What a waste: solid waste management in Asia (No. 19328, p. 1). The World Bank.
13. Hoornweg, D.; Bhada-Tata, P. 2012. What a Waste : A Global Review of Solid Waste Management. Urban development series;knowledge papers no. 15. World Bank, Washington, DC. © World Bank.
14. Jaglo, K., Kenny, Sh., and Stephenson, J. 2021. From Farm to Kitchen: The Environmental Impacts of U.S. Food Waste. EPA (Environmental Protection Agency). [Available at: https://www.epa.gov/system/files/documents/2021-11/from-farm-to-kitchen-the-environmental-impacts-of-u.s.-food-waste_508-tagged.pdf].
15. Jouhara, H., Czajczyńska, D., Ghazal, H., Krzyżyńska, R., Anguilano, L., Reynolds, A.J. and Spencer, N. 2017. Municipal waste management systems for domestic use. *Energy*, 139, 485-506.
16. NSWAI (National Solid Waste Association of India). 2013. International Conference on Waste Wealth and Health 2013, MPCST, Bhopal, M.P., India, 15-17 February 2013.
17. Othman, A.A.; Obaid, A.K.; Al-Manmi, D.A.M.; Pirouei, M.; Salar, S.G.; Liesenberg, V.; Al-Maamar, A.F.; Shihab, A.T.; Al-Saady, Y.I.; Al-Attar, Z.T. 2021. Insights for Landfill Site Selection Using GIS: A Case Study in the Tanjero River Basin, Kurdistan Region, Iraq. *Sustainability*, 13, 12602. (DOI: https://doi.org/10.3390/su132212602).
18. Parker, B. 2002. Planning Analysis: Calculating growth rate. University of Origon.
19. Qdais, H.A. 2007. Techno-economic assessment of municipal solid waste management in Jordan. *Waste management*, 27(11), 1666-1672.
20. Rashid, Ch. R., Tahir, J. J., and Mustafa, O. M. 2018. Solid Waste Management: A Case Study in Chamchamal (Dwbra Valley Open Dump), Sulaimani, Kurdistan Region. Geoscience Session, Conference Paper · August 2018. (DOI: 10.31530/17025).
21. Seadon, J.K. 2010. Sustainable waste management systems. *Journal of cleaner production*, 18(16-17), 1639-1651.
22. Shekha, Y. A. 2011. Household Solid Waste Content in Erbil City, Iraqi Kurdistan Region, Iraq. *Zanco Journal*, 23, 3.
23. Srivastava, V., Ismail, S.A., Singh, P. and Singh, R.P., 2015. Urban solid waste management in the developing world with emphasis on India: challenges and opportunities. *Reviews in Environmental Science and Bio/Technology*, 14(2), 317-337.
24. UN. 1952. Estimates derived by extrapolation of census results. MannuaI. Methods of Estimating Total Population for Current dates, 10.
25. UNESCAPE. 2015. Average growth rate: Computation methods. Stats Brief. Statistic division, April 2015, Issue no. 7, United Nations ESCAPE.
26. Zaman, A.U., 2013. Life cycle assessment of pyrolysis–gasification as an emerging municipal solid waste treatment technology. *International Journal of Environmental Science and Technology*, 10(5), 1029- 1038.